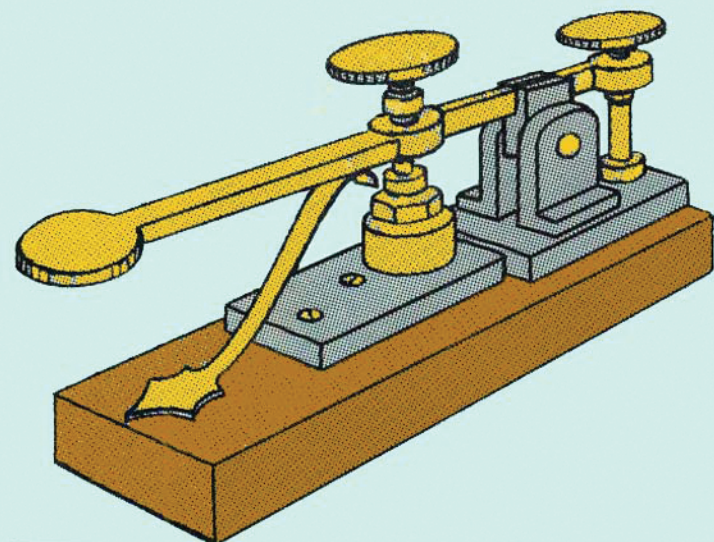
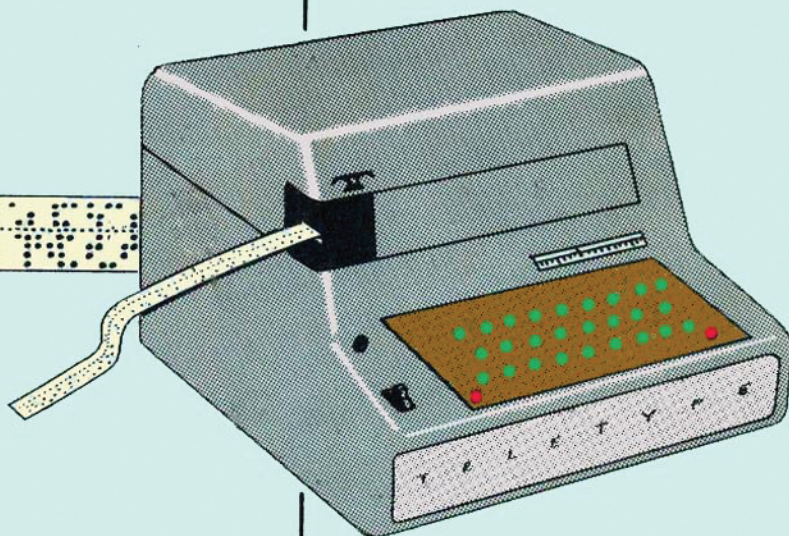
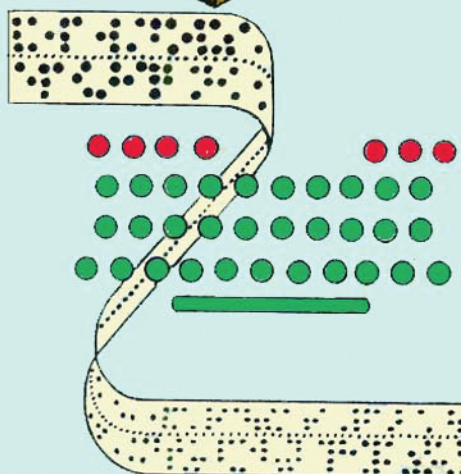
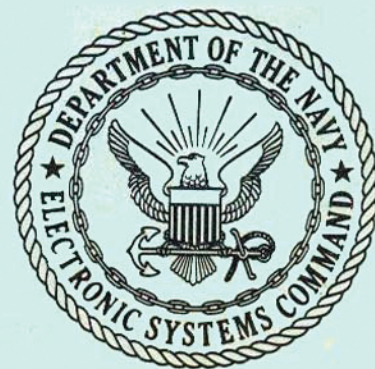


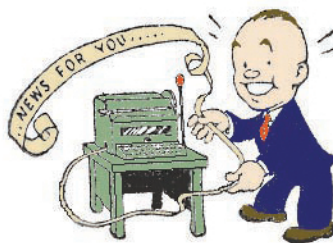


PRINCIPLES OF TELEGRAPHY (Teletypewriter)



DEPARTMENT OF THE NAVY
ELECTRONIC SYSTEMS COMMAND





**PRINCIPLES OF TELEGRAPHY
(TELETYPEWRITER)**

**DEPARTMENT OF THE NAVY
ELECTRONICS SYSTEMS COMMAND
WASHINGTON, D. C.**

APPROVED JUNE 1967

PREFACE

This handbook is devoted to the principles and practices of telegraphy as applied to the teletypewriter. It is designed as an introductory text for students and engineers who are concerned with practical systems and equipments within the military services.

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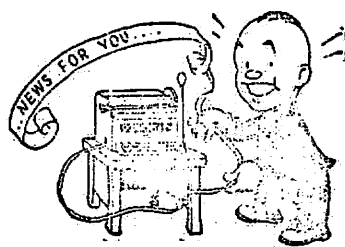
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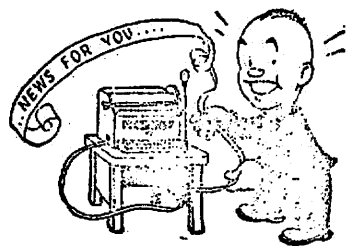
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PART A
INTRODUCTION AND HISTORICAL
BACKGROUND



Part A

Introduction and Historical Background

1.0 INTRODUCTION

For centuries men of all nations and many positions in life have recognized the need for rapid communication, and have devoted their attention to devising the ultimate communications medium. Through these efforts, many curious devices have evolved and are cited in the annals of all nations. Fire, smoke, bells, trumpets, drums, and guns have all played a part; many primitive devices are still to be found in use in some parts of the world. For example, the use of flags and various forms of semaphore signaling date from the thirteenth century, and are still retained in modified forms for use at sea. Another type was the heliograph, a system employed for visual signaling in sunlight, which reflected the sun's rays from one point to another. However, this method was limited, for in dull weather and at night lamp signaling had to be used. The vagaries of nature render communication by such systems somewhat precarious. Even under ideal conditions only a restricted range of direct operation is possible and the speed of operation is relatively slow and cumbersome. Eventually, the advent of telegraphy was to overcome these disadvantages.

The word telegraphy is derived from the Greek *tele*, meaning afar, and *graphos*, meaning that writes; hence telegraphy is concerned with those systems employed for the communication at a distance of the written word, as distinct from telephony, which is concerned with the communication of the spoken word. Telegraphy is the oldest branch of telecommunications and, although the advent of telephony dealt a severe blow in certain applications of telegraphy, the latter has nevertheless continued to prosper. In fact, contrary to early predictions that telephony would completely supersede telegraphy, experience has shown that telegraphy and telephony are not competing systems of communication, but that each has separate and distinct fields of usefulness and that in many cases they are complementary. Telegraphy has the unique advantage of providing a permanent record of the intelligence transmitted and for many types of communication this is essential.

The term "telegraph" is used to refer collectively to all forms of binary code electrical communications. The

terms "teletypewriter" and "manual telegraphy" are used to denote specific methods of telegraph communication.

2.0 HISTORICAL BACKGROUND

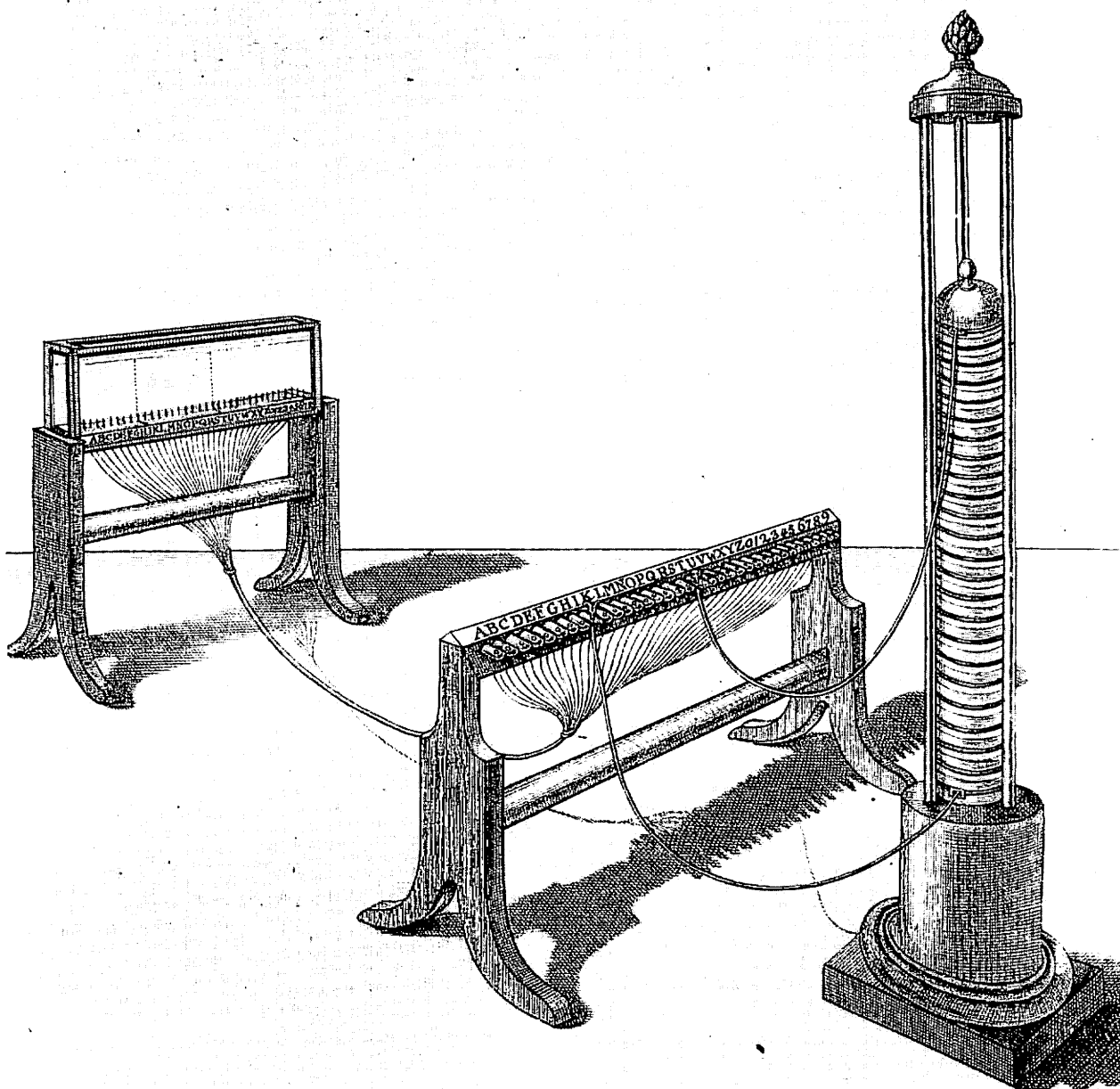
In 1809 a Bavarian professor, Samuel T. Soemmerring, successfully transmitted information by use of electric current. His discovery was the galvanic telegraph shown in Figure A-1. His telegraph was based on the discovery of electrolysis of water.

By using 35 wires attached to 35 gold electrodes placed in the bottom of a tank of water with glass walls, Soemmerring could indicate any two letters of the German alphabet (or any numeral) by connecting the appropriate electrodes to a voltaic pile. An effervescence at the two electrodes revealed the proper pair, with the first symbol in the sequence indicated by a greater amount of gas forming at the negative electrode than at the positive electrode. By using such a detector, he could transmit signals through 2000 feet of wire. Although Soemmerring's invention was only a "philosophical toy," and no tests were made of it over actual land lines, it was still the first galvanic telegraph that was developed and it stimulated development of other electrical telegraphs.

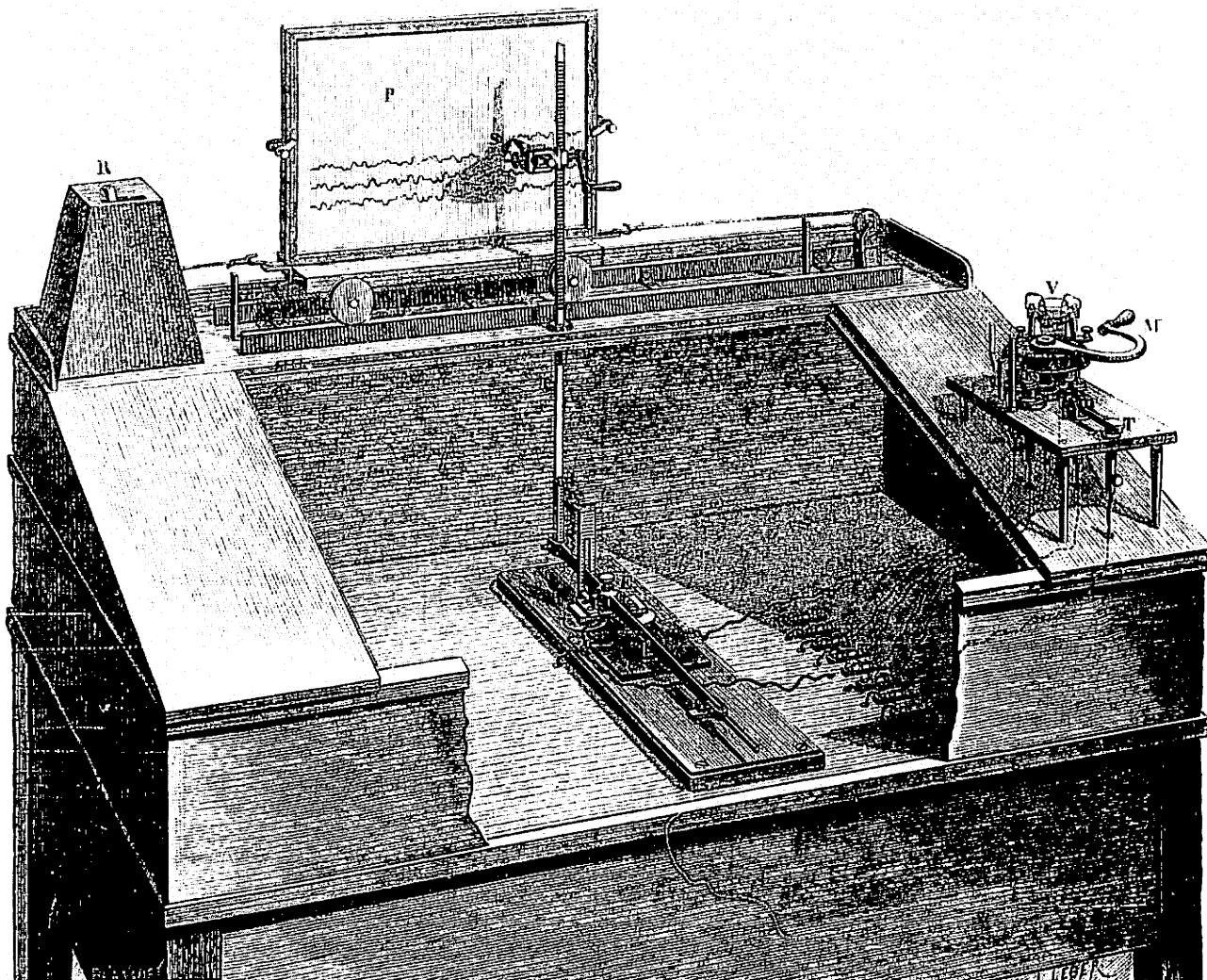
During the 1830's a number of inventors recognized the possibility that a binary code might reduce the number of wires necessary to transmit electrical telegraphs.

M. H. Jacobi in 1839 produced the recording telegraph for the Russian government shown in Figure A-2. This instrument consisted of an electromagnet at the receiving station which was actuated by a key at a distant point that closed the circuit. The resulting up and down motion of the armature was recorded as a wavy line on a moving plate. This instrument was used in 1839 on an experimental underground line in St. Petersburg that ran from the Winter Palace across the square to the General Staff Building.

The first inventor actually to set up an electric telegraph in the United States was Harrison G. Dyar. Between the years 1826-1828 Dyar worked out an electrochemical system whereby messages were recorded by



(Courtesy of Smithsonian Institution, Washington, D.C.)
SOEMMERRING'S ELECTROCHEMICAL TELEGRAPH OF 1809
FIGURE A-1



(Courtesy of Smithsonian Institution, Washington, D.C.)
**JACOBI'S RECORDING TELEGRAPH OF 1839, AS SHOWN AT
THE PARIS INTERNATIONAL ELECTRICAL EXHIBITION OF 1881
FIGURE A-2**

sparks passing through chemically treated paper. The message was indicated by the resultant dot-dash pattern formed by the discolorations. Dyar's telegraph was tried out near a race track on Long Island by setting up poles with insulators to carry the single wire that formed half the circuit, and by using the earth as a ground return for the other half of the circuit.

Samuel F. B. Morse was the first American to patent a practical electromagnetic system of telegraphy. Instead of basing the receiving instrument upon the torsion of a needle in a galvanometer coil or upon electrolysis, Morse based his telegraph on the direct pull of an electromagnet. Morse, with his associates Leonard Gale and Alfred Vail, contrived a relay that would repeat the signal from one 10-mile circuit to the next. Their equipment, consisting of register, key, and relays, was issued a U.S. patent in June 1840. (See Figures A-3, A-4, and A-5.) The earliest manual telegraph systems used coded characters that had a variable number of elements per character. Samuel F. B. Morse developed the character encoding system based on the frequency of alphabetical occurrence of each character in the English alphabet. Thus the most frequently used alpha-character has the shortest encoded symbol and the least used alpha-character was assigned the largest code. This method of determining the character codes added efficiency to the use of the coded system.

Designed for manual operation, Morse codes give surprisingly fast operation with skilled operators. The American Morse code has short spaces within some letters, and uses three different dash lengths. It differs in 11 letters from the Continental or International Morse Code. The short dots and longer dashes are formed manually by the operator, using a key that closes and opens the line circuit. Early systems received these signals on a device that made marks representing current on paper tape and left spaces for the no-current condition.

By the end of the 1840's other telegraph systems in the United States were in competition with Morse's system, for his invention had proven to be a profitable one. An important competitor of the Morse system was the letter printing telegraph. In 1846, Royal E. House of Vermont invented a printing telegraph, shown in Figure A-6, whose transmitter had a set of keys similar to those of a piano. There was a key for each letter of the alphabet, and each key produced a certain number of electrical impulses. At the receiving station these impulses advanced a type wheel until the letter signaled by the transmitter was reached and stamped on a paper tape. In the meantime the tape had advanced to receive the selected letter.

The House instrument was replaced by a better system in 1856, invented by David Hughes, a professor of

music in Kentucky. Hughes's instrument, Figure A-7, was based on the synchronous movement of corresponding parts at transmitter and receiver. These movements were kept in synchrony by setting a vibrating spring so that it produced a musical note of a certain pitch. The Hughes telegraph could be used over longer lines than could the House device, and later models were used on the continent of Europe as a printing telegraph until the turn of the century.

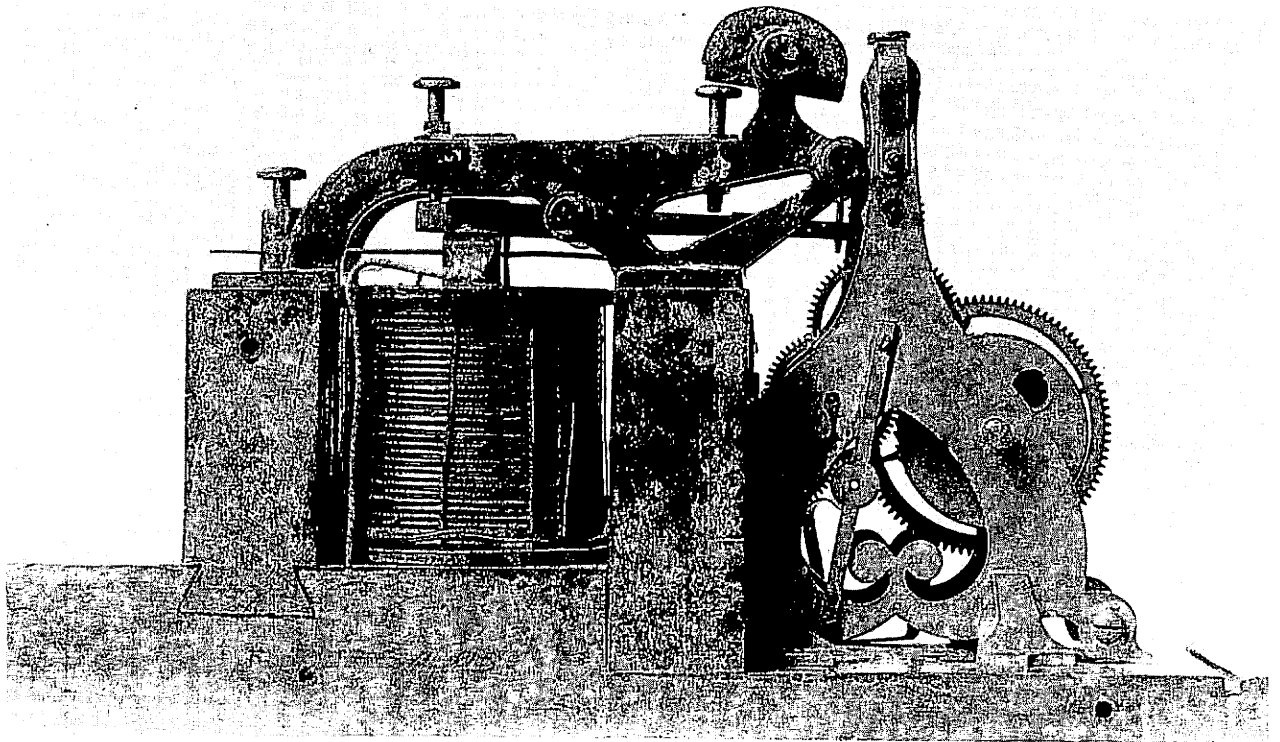
By 1865, the telegraph was well established in the world with 16,000 miles of telegraph lines in Great Britain, 64,000 miles in France, and 28,000 miles in Prussia. In the United States, the Civil War had interfered with normal economic growth, but by the end of the war there were 83,000 miles of telegraph lines in the country.

Because of the expanding need for improved communications, inventors sought to devise telegraph systems which sent a number of messages over a single wire. One type devised was the duplex circuit which permits two-way passage of messages simultaneously over the same wires. From the duplex circuit evolved quadruplex which handles four messages simultaneously (two in each direction). A logical outgrowth of these methods was a system that could provide a number of channels over a single circuit and is called a multiplex system. (See Figure A-8.)

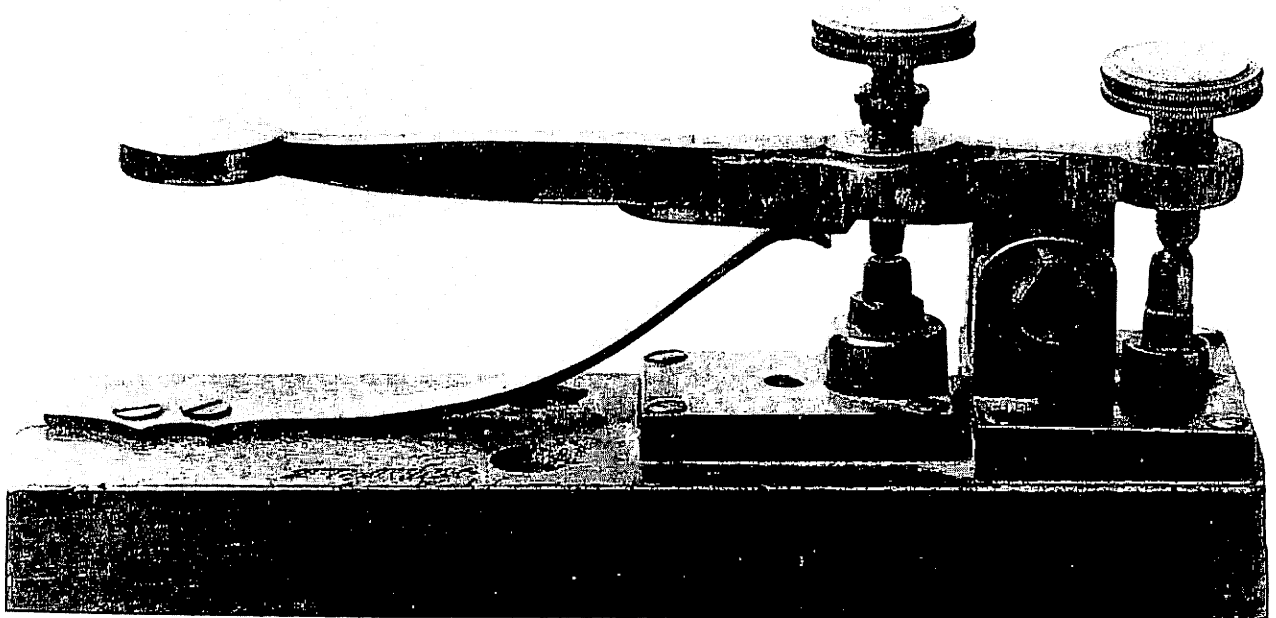
Multiplexing was originally a mechanical method that used a distributor to switch rapidly among several printing telegraph channels. Each transmitter and its corresponding distant receiver are sequentially connected over a single line on a time-shared basis. The distributor, similar to the distributor of an automobile, was placed at each end of a telegraph line. The motion of the sending and receiving brushes was synchronized to join corresponding stations at proper intervals. Sophistication of this multiplex developed into what is presently called Time-Division-Multiplex (TDM).

In 1874, J. M. E. Baudot of France devised a workable multiplex system shown in Figures A-9, A-10, and A-11. Use of Baudot's system spread throughout France during the 1880's; during the late 1890's it was introduced in England. Further improvements to the Baudot system and its combination with other systems led to the present printing telegraph system.

Multichannel operation resulted in the improved traffic capacity and led to the introduction of the 5-unit code. This 5-unit code provided a unique code for 32 alphanumeric characters. In this code, each character was generated by the unique combination of five code elements, as selected on a keyboard equipped with five keys (Figure A-9). There was one keyboard at each transmitting position and a number of these positions



(a) The Original Register Used in Baltimore-Washington Trials of 1844



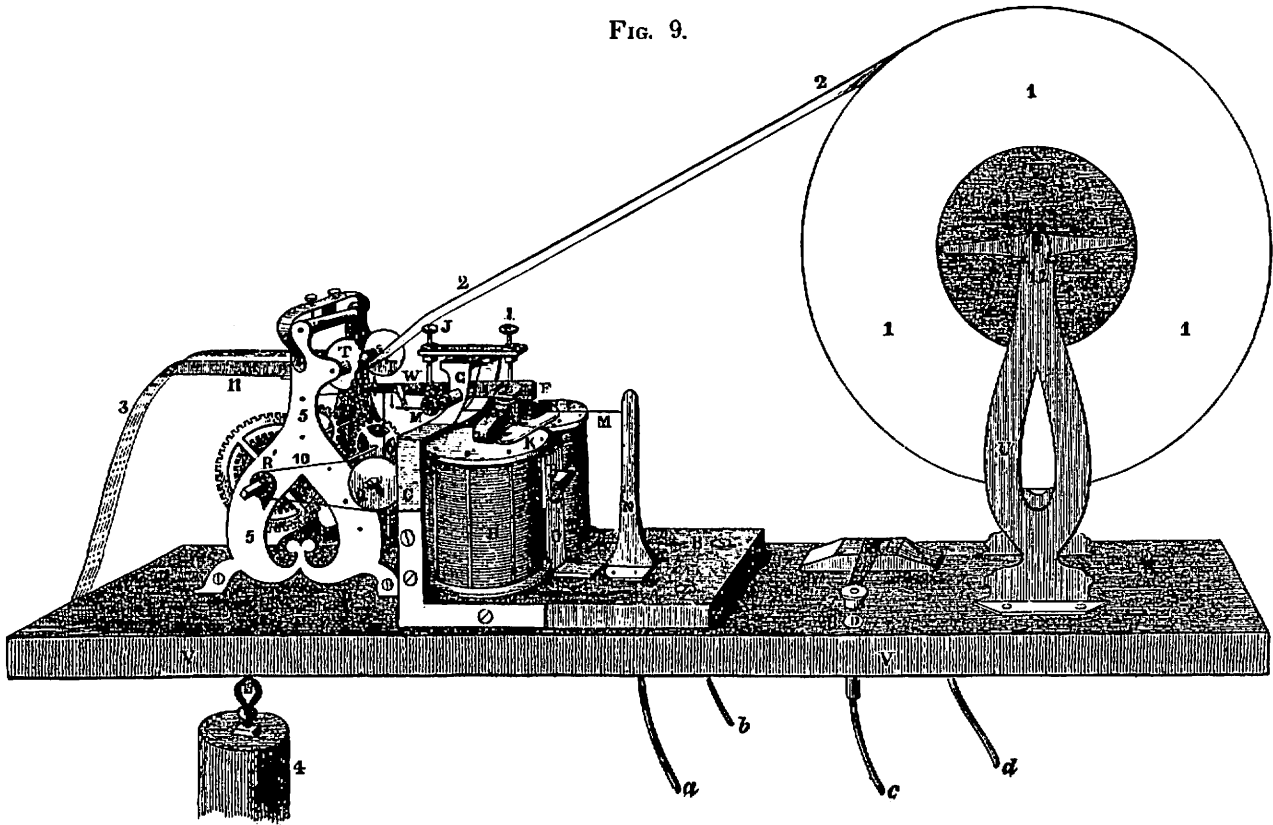
(b) Original Telegraph Key Used in the Mid-1840's

(Photographs courtesy of Smithsonian Institution, Washington, D.C.)

THE MORSE-VAIL TELEGRAPH

FIGURE A-3

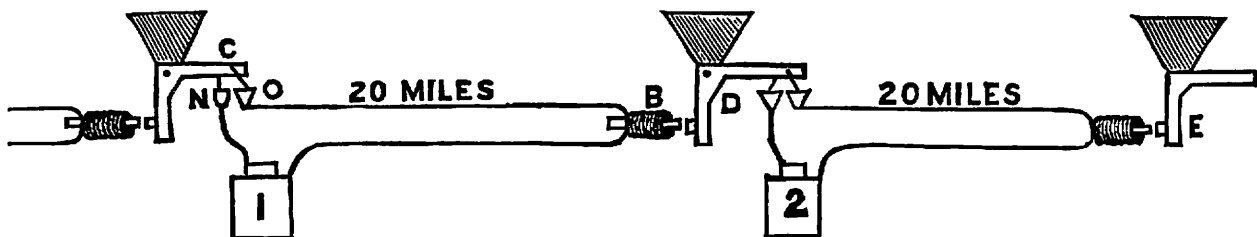
FIG. 9.



(Courtesy of Smithsonian Institution, Washington, D.C.)

MORSE-VAIL 1845 TELEGRAPH

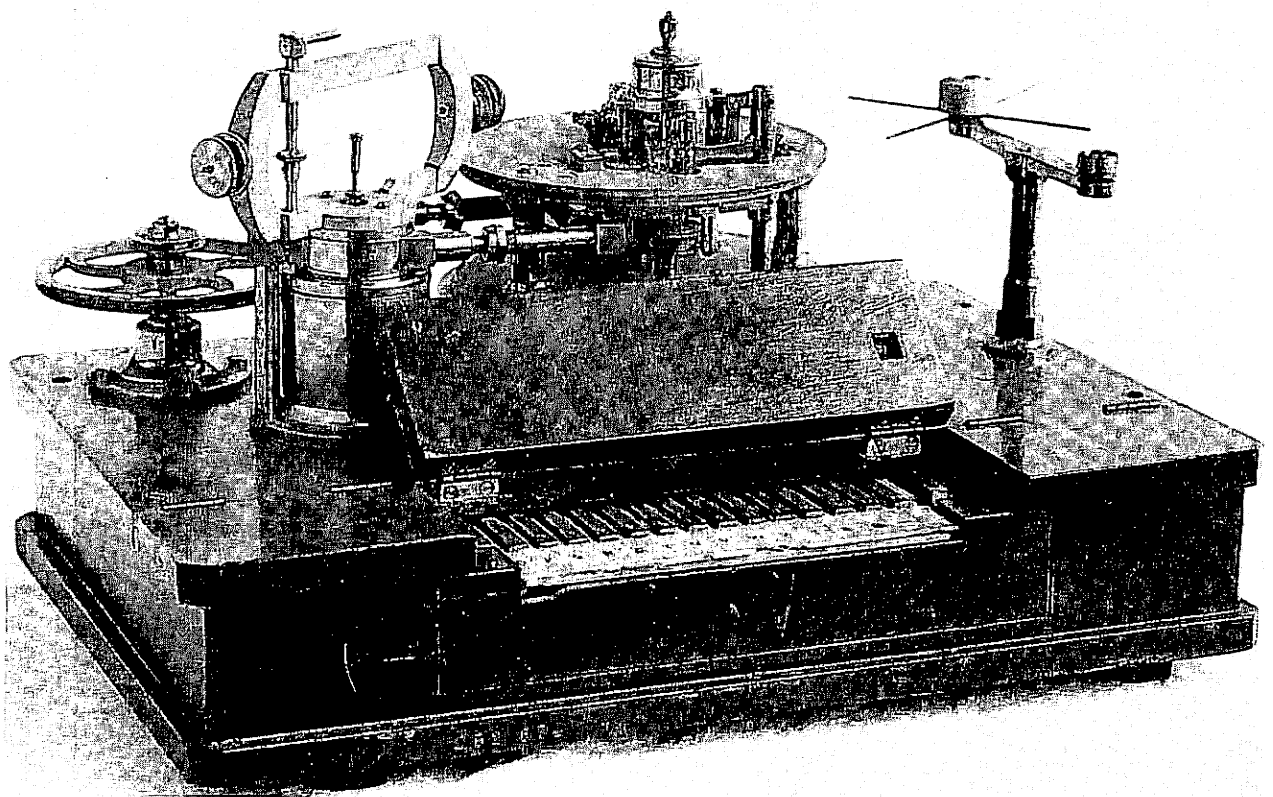
FIGURE A-4



(Courtesy of Smithsonian Institution, Washington, D.C.)

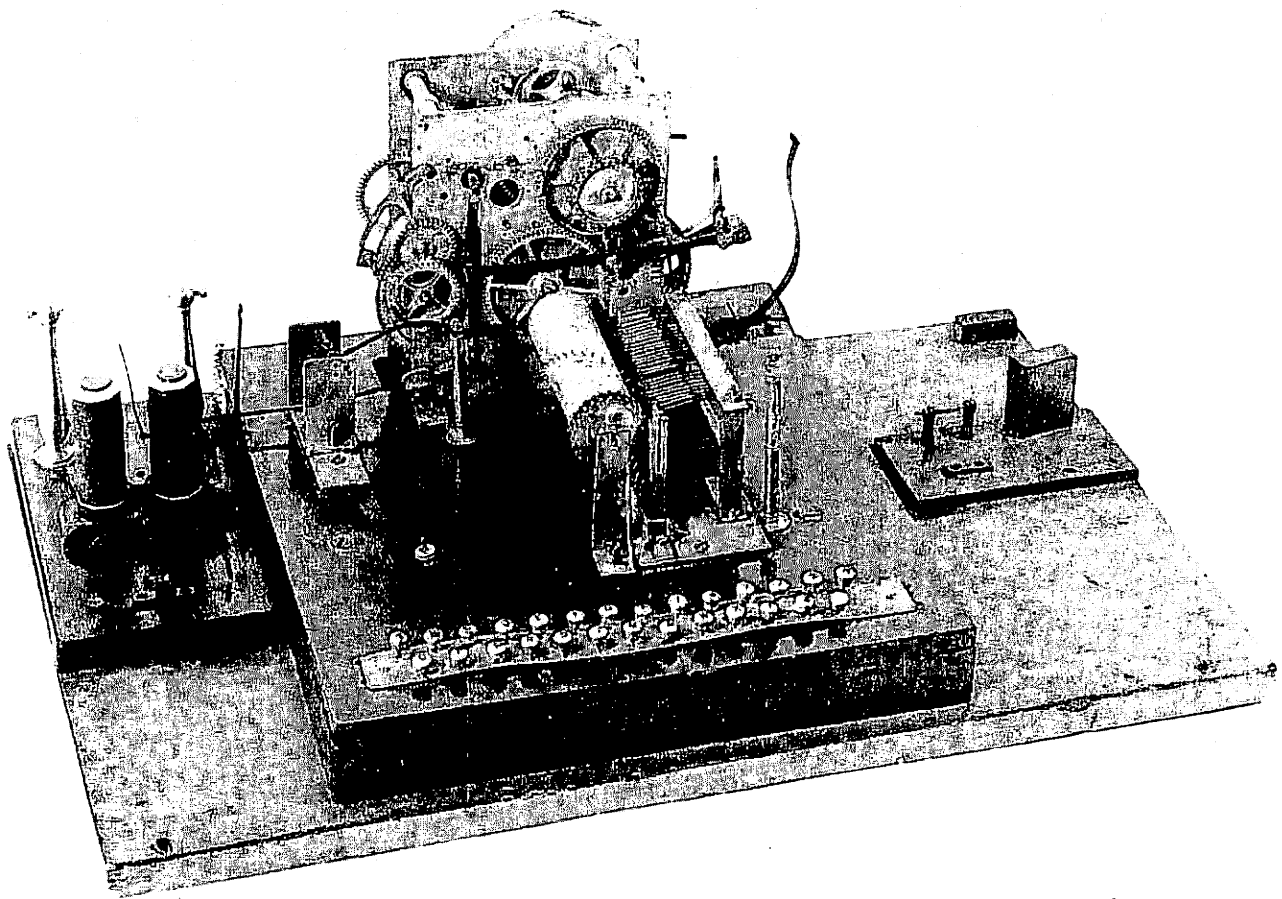
MORSE RELAY PLAN OF 1837

FIGURE A-5

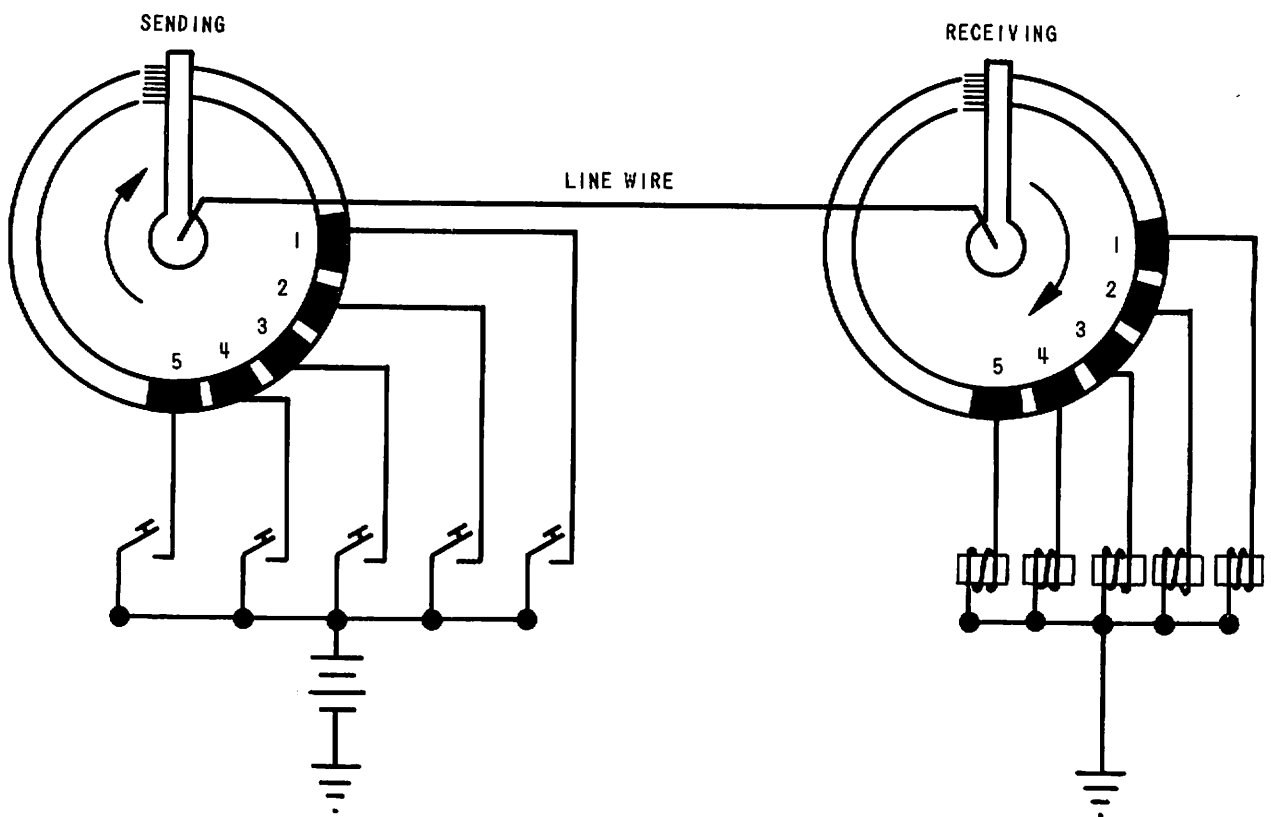


(Photograph courtesy of Smithsonian Institution, Washington, D.C.)

**PATENT OFFICE MODEL OF HOUSE'S PRINTING TELEGRAPH
FIGURE A-6**

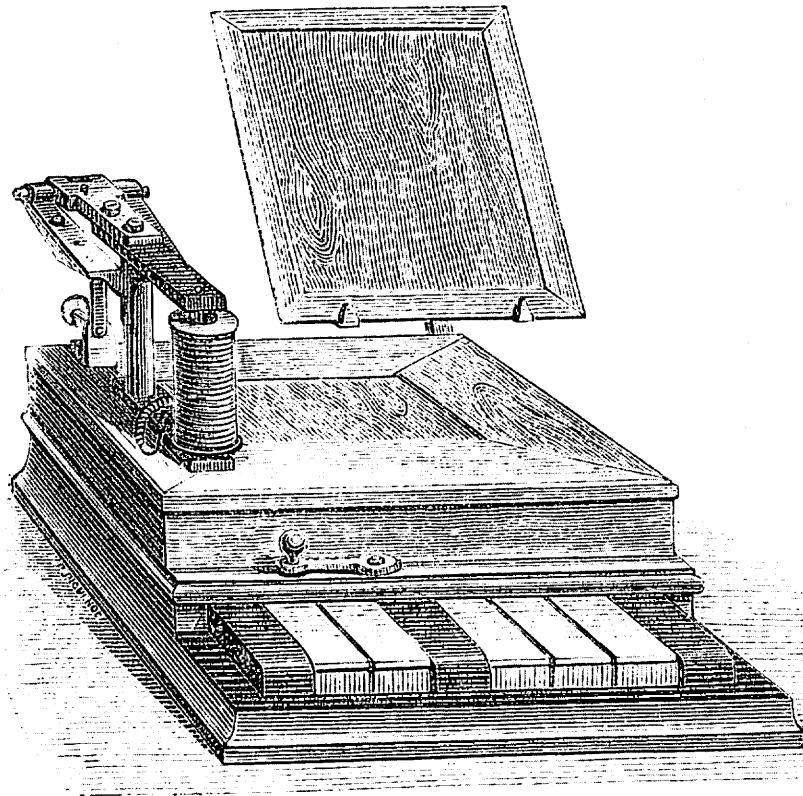


(Photograph courtesy of Smithsonian Institution, Washi.
PATENT OFFICE MODEL OF HUGHES' PRINTING
FIGURE A-7



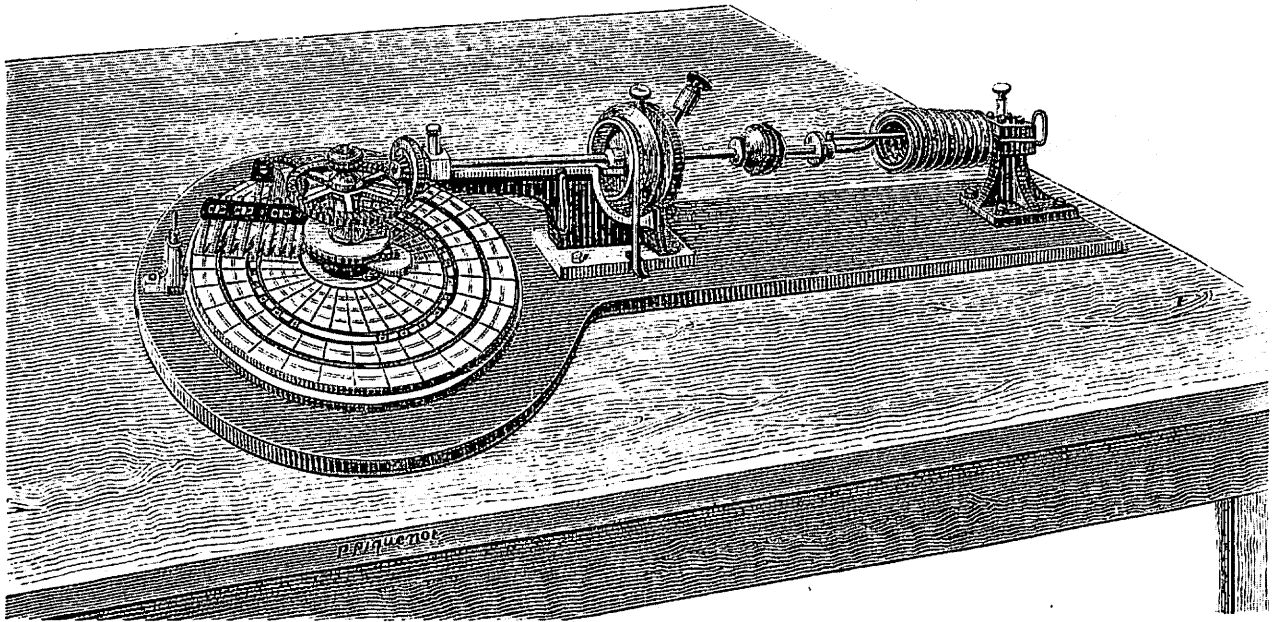
*(From Electrical Communications by Albert: New York, 1940.
Used by permission of John Wiley and Sons.)*

**SCHEMATIC DIAGRAM OF A PAIR OF MULTIPLEX DISTRIBUTORS
FIGURE A-8**

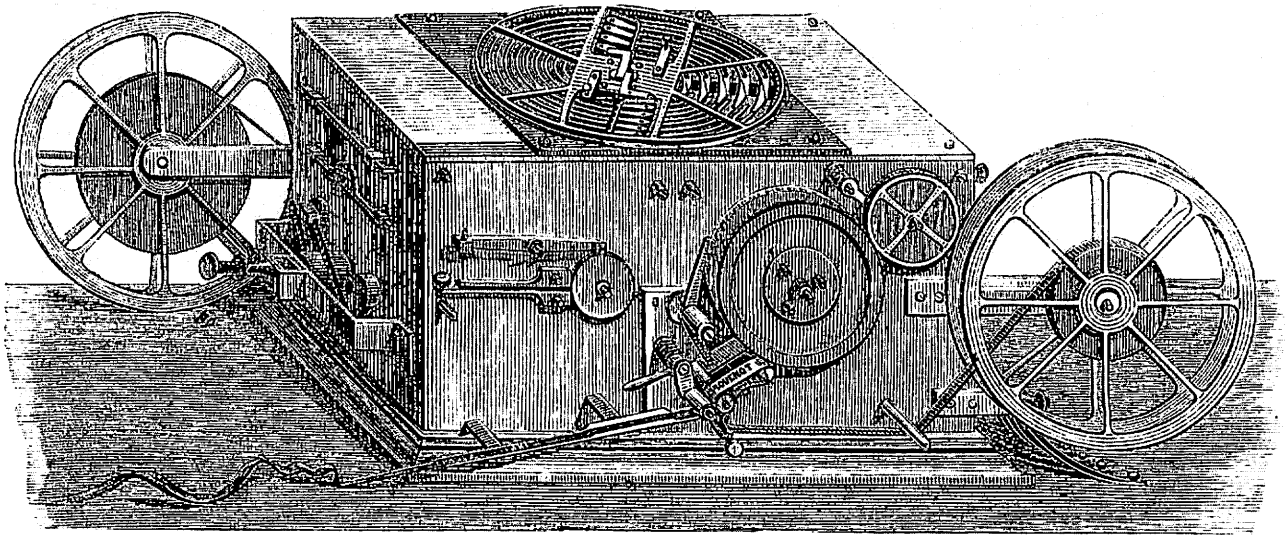


(Courtesy of Smithsonian Institution, Washington, D.C.)

BAUDOT'S MULTIPLEX TELEGRAPH TRANSMITTER KEYBOARD
FIGURE A-9



(Courtesy of Smithsonian Institution, Washington, D.C.)
BAUDOT'S MULTIPLEX TRANSMITTER DISTRIBUTOR COMMUTATOR
FIGURE A-10



(Courtesy of Smithsonian Institution, Washington, D.C.)
ONE OF THE BAUDOT MULTIPLEX RECEIVERS
FIGURE A-11

were connected to the distributor. The distributor connected each keyboard in succession to the line. Usually four channels were used; if so, there were four sectors on the distributor with one sector for each keyboard. Each sector was further subdivided with one segment for each key of the keyboard corresponding to that sector. As the brush on the distributor moved over the segments, each key of a given keyboard was connected in succession to the line. An identical distributor, moving synchronously at the receiving station, switched the combination of signals to four groups of polarized relays, each relay being connected to one of five segments of the four sectors of the receiving distributor. Each group of relays actuated a certain one of the four printers at the end of the line. With the Baudot device, the operator at each transmitting position could send about 25 words per minute.

The Baudot invention was a 4-channel time-division-multiplex system. The 5-unit code yielded 2^5 or 32 permutations.

The 32 combinations of the code were insufficient to handle the required alphabet. This difficulty was solved by dividing the information characters into two categories. The letters included 27 alphabetical characters (including the French E') and a character shown as t. Figures consisted of the 10 numerals, punctuation marks, and other symbols. An erasure character was included in both categories. The receiving tape printer had two possible responses to a given code combination. Following the so-called "letters blank" character, it would print letters. Reception of "figures blank" shifted the receiver to print only characters in the figures category thereafter. Thus, between groups of letters and figures, a "shift" character was interposed. This proved to be a practical solution that has been retained to the present day.

Figure A-12 shows the original Baudot code and alphabet. The code elements column denotes the character encoding used for transmission. Subsequently, this became the International Telegraph Alphabet No. 1 (Figure A-13) of the Comité Consultatif International Télégraphique et Téléphonique (CCITT), with slight modifications to meet the needs of page-printers by changing E' to carriage return, and t to fresh line (line feed). Modern so-called Baudot codes are not derived from the Baudot code, but from the Murray code.

About 1901, Donald Murray made an improved time-division-multiplex system with a tape printer and a typewriter-style keyboard. He used a 5-unit code with two shifts, but the assignment of characters to the code combinations was entirely different from that of the Baudot code. This was due largely to the use of a three-row typewriter-style keyboard, with the numerals assigned to the top row of keys. Therefore, the numeral 1 had to use the same combination as the letter Q, 2 the same combination as W, etc. The Murray code is shown in Figure A-14. It was the basis for the present CCITT International Telegraph Alphabet No. 2.

The Baudot, Murray, and other multiplex systems gave efficient service between telegraph offices, but they were not practical for serving individual customers because of the complex synchronizing arrangements required. This limitation was overcome by the invention of the "start-stop" transmission system. The first practical start-stop system retaining the basic Murray code was brought out by C. L. Krumm and H. Krumm in the United States in 1907.

In transmitting a character, the five information elements are preceded by a unit-duration start element, and followed by a stop element having a minimum duration that varies in different systems from 1.0- to 2.0-unit intervals. A common value in the United States is 1.42, so that the total duration of a coded character (or character interval) is 7.42-unit intervals. This has led to the term start-stop code, denoting the start and stop elements as part of the code. The start-stop system is now in general use.

In recent years, need has arisen for codes with greater information capacity for use in transmitting data over communication circuits and to facilitate the design of teletypewriters with keyboards more closely resembling those of office typewriters, having a four-row keyboard, without the need to shift between letters and numbers. A code with six information bits per character allows 64 (2^6) combinations, while a 7-unit code allows 128 (2^7) combinations. Some interest has been shown in 6-unit codes, especially in Europe, but the desire for still greater capacity had led to development of several codes with seven information bits. Since the great majority of military users for some time to come will be using 5-unit equipment, emphasis will be placed on this type of system. A comprehensive discussion of telegraph codes is provided in Part C, for further study.

CHARACTERS		CODE ELEMENTS				
LETTERS CASE	FIGURES CASE	I	II	III	IV	V
A	1	●				
B	8			●	●	
C	9	●		●	●	
D	0	●	●	●	●	
E	2		●			
E'	&	●	●			
F	<u>E</u>		●	●	●	
G	7		●		●	
H	<u>H</u>	●	●		●	
I	<u>0</u>		●	●		
J	6	●			●	
K	(	●			●	●
L	=	●	●		●	●
M	)		●		●	●
N	N ^o		●	●	●	●
O	5	●	●	●		
P	%	●	●	●	●	●
Q	/	●		●	●	●
R	-			●	●	●
S	;			●		●
T	!	●		●		●
U	4	●		●		
V	'	●	●	●		●
W	?		●	●		●
X	,		●			●
Y	3			●		
Z	:	●	●			●
<u>t</u>	.	●				
✱	✱	ERASURE			●	●
FIGURE BLANK					●	
LETTER BLANK						●

LEGEND ● Marking Element
 Spacing Element

BAUDOT 5-UNIT CODE
 FIGURE A-12

CHARACTERS		CODE ELEMENTS					REMARKS
LETTER CASE	FIGURE CASE	1ST.	2ND.	3RD.	4TH.	5TH.	
A	I						 INDICATES POSITIVE CURRENT
B	8						
C	9						
D	0						
E	2						
F	SEE NOTE 1.						INDICATES NEGATIVE CURRENT
G	7						
H	+						
I	SEE NOTE 1.						
J	6						
K	(						NOTE 1. AT THE DISPOSAL OF EACH ADMINISTRATION FOR ITS INTERNAL SERVICE.
L	=						
M	)						
N	SEE NOTE 1.						
O	5						
P	%						NOTE 2. FOR PAGE PRINTING INSTRUMENTS
Q	/						
R	-						
S	.						
T	SEE NOTE 1.						
U	4						
V	' (APOSTROPHE)						
W	?						
X	, (COMMA)						
Y	3						
Z	: (COLON)						
CARRIAGE RETURN	CARRIAGE RETURN						
FRESH LINE SEE NOTE 2	FRESH LINE SEE NOTE 2						
LETTER BLANK (SPACE)	LETTER BLANK (SPACE)						
FIGURE BLANK (SPACE)	FIGURE BLANK (SPACE)						
*(ERROR)	*(ERROR)						
INSTRUMENT AT REST	INSTRUMENT AT REST						

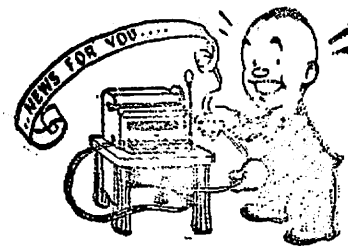
CCITT INTERNATIONAL TELEGRAPH ALPHABET NO. 1
FIGURE A-13

CHARACTERS		CODE ELEMENTS				
LETTERS CASE	FIGURES CASE	1	2	3	4	5
A		●	●			
B	?	●			●	●
C	(		●	●	●	
D	2	●			●	
E	3	●				
F	1/	●		●	●	
G	3/		●		●	●
H	5/			●		●
I	8		●	●		
J	7/	●	●		●	
K	9/	●	●	●	●	
L	/		●			●
M	'			●	●	●
N	-			●	●	
O	9				●	●
P	0		●	●		●
Q		●	●	●		●
R	4		●		●	
S	1	●		●		
T	5					●
U	7	●	●	●		
V	)		●	●	●	●
W	2	●	●			●
X	£	●		●	●	●
Y	6	●		●		●
Z	.	●				●
FIG SPACE	FIG SPACE	●	●		●	●
LTR SPACE	LTR SPACE			●		
LINE PAGE	LINE PAGE				●	
* #	* #	●	●	●	●	●
COL	COL		●			

LEGEND ● Marking Element
 Spacing Element

**MURRAY 5-UNIT CODE
FIGURE A-14**

PART B
TELEGRAPH TRANSMISSION PRINCIPLES



Part B

Telegraph Transmission Principles

1.0 GENERAL

In teletypewriter transmission, the primary concern is reproduction of a message at the receiving end without error and interference to other services. Teletype systems employ direct current (DC) transmission for short distances extensively. In this transmission medium, circuit characteristics govern the distance over which satisfactory operation may be expected. These DC systems primarily use open-wire, cable, and various types of insulated field wire. In military operations, DC operation is used on teletypewriter circuits between headquarters where the lines are of comparatively short distances and where comparatively few circuits are needed.

Long-haul teletype traffic is carried by carrier systems or radio channels. Carrier transmission of teletypewriter signals is accomplished by systems that make use of either voice-frequency or high-frequency alternating current (AC) to carry many simultaneous signals over a single line. At the receiving end, the AC is reconverted into DC to operate the teletypewriter equipment.

The great majority of long-haul telegraph circuits now employ voice-frequency carrier systems, providing up to 24 telegraph circuits from a transmission facility that would otherwise be capable of only a single telephone circuit. Before the advent of such carrier systems, practically all long telegraph circuits were derived from open-wire or cable facilities. Some of these facilities were used simultaneously for telephone transmission. This required the employment of some device that would separate the telephone currents from telegraph currents at each line terminal. The devices commonly used were known as either simplex sets or composite sets. In present-day telegraph practices, simplex and composite sets are employed chiefly for deriving relatively short telegraph circuits as branches or legs extending from a central point on a main long-haul route.

2.0 TELEGRAPH CIRCUITS

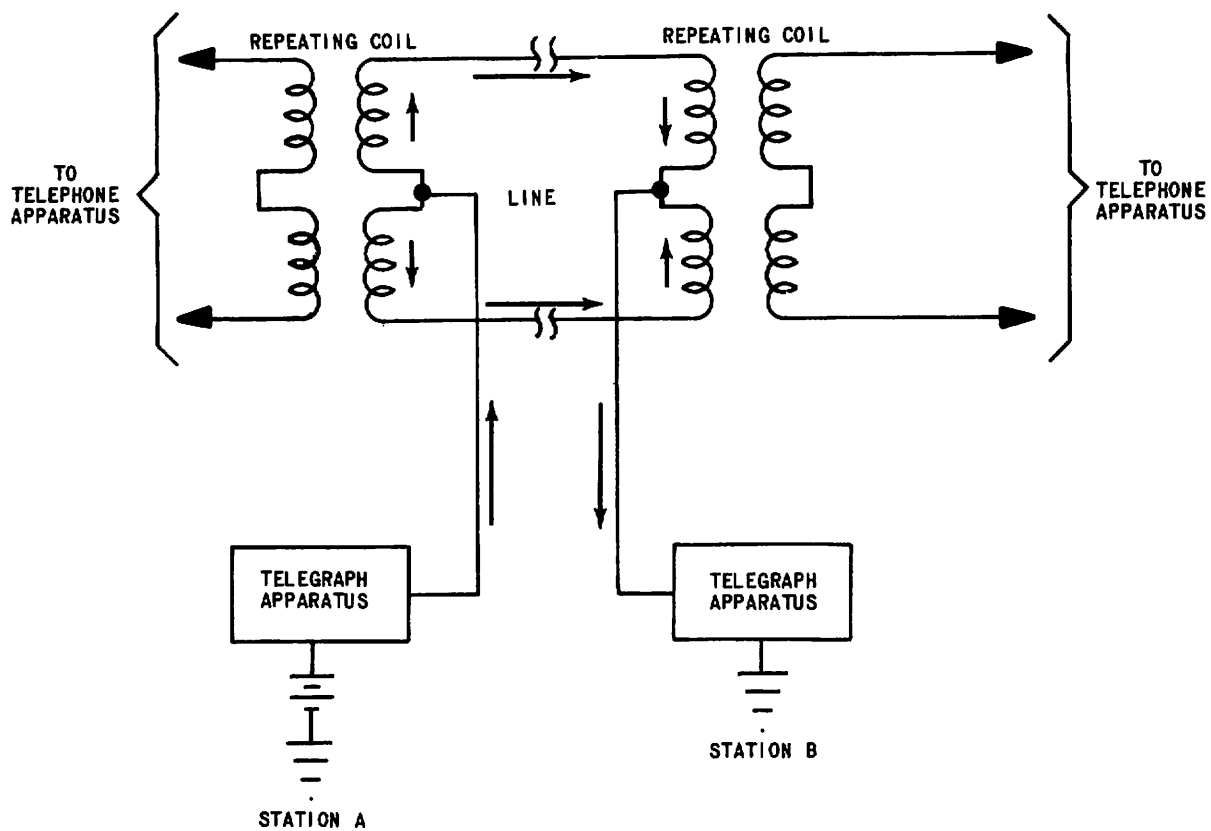
2.1 Simplex Method

In the simplex method of DC telegraphy, a telegraph or teletypewriter circuit is derived from an existing telephone circuit. A repeating coil is installed at each end of the telephone circuit, and the telegraph apparatus is connected between the midpoint of the line windings of each repeating coil and ground, as shown in Figure B-1. It is connected in this manner to achieve balance; this is the fundamental principle of the simplex system. Current from the telegraph apparatus at station A divides and flows in opposite directions through the line windings of the repeating coil. The current then travels over both line wires in parallel, through the line windings (in opposite directions) of the repeating coil at station B, and through the telegraph apparatus to ground. The telegraph currents in the line windings of each repeating coil are opposing and will induce no net voltage in the drop-side windings of the coils. In a perfectly balanced telephone circuit, no interference to normal operation will result from the operation of the telegraph circuit.

Satisfactory operation requires that the two line conductors have identical electrical characteristics. This includes not only equal or balanced series resistance, but also equal capacitances and leakages to other conductors and to ground. Otherwise, the telegraph currents will not divide into equal parts at the midpoint of the line windings. Any unbalance will induce currents in the drop-winding of the coils, which may be heard as clicks or thumps on the telephone circuits.

2.2 Composite Method

The principle of the composite set differs radically from that of the simplex set. The composite set permits a grounded telegraph circuit to be derived from each of the two wires of a telephone circuit without interfering with the alternating telephone currents. This set utilizes the frequency range below that required



TELEGRAPH CIRCUIT ON SIMPLEXED TELEPHONE CIRCUIT
FIGURE B-1

for the transmission of speech, for transmitting telegraph signals.

The transmission of speech on commercial telephone circuits is contained within a frequency band of about 250 to 2600 cycles per second (cps). Thus, it is possible to use the frequency range 0 to 250 cps of a telephone circuit for telegraph transmission, provided, however, that precautions are taken to avoid mutual interference between the working of the telegraph and telephone circuits. It must also be ensured that the telegraph circuit causes no degradation of the telephone circuit characteristics. This method of deriving a telegraph circuit from a telephone circuit is known as compositing. A sketch of a composite set designed for a grounded telegraph is shown in Figure B-2. The composite set consists essentially of a high-pass filter in series with the telephone circuit, and a low-pass filter in the telegraph branch. These filters have minimal distortion and attenuation in their respective working ranges.

The working range of the telegraph branch is approximately 80 cps, and the filter in the telephone branch passes frequencies as low as 250 cps. The regular 20-cycle ringing current cannot be used on composited telephone circuits; however, 135-cycle signaling arrangements can be employed. Although there is considerable attenuation of 135 cycles over the telephone channel, sufficient signal is transmitted to operate signaling apparatus tuned to 135 cycles.

The inductance of the retardation coil in series with the telegraph branch (Figure B-2), plus the capacitors connected in parallel to ground, prevent any sudden current changes from appearing as audible clicks in the telephone circuit. The inductance opposes the sudden current increase at the moment of circuit closure, and retards its rate of decay when the circuit is opened. The capacitors aid in this action by storing the electrical energy when the circuit is closed, and by discharging it through the inductance when the circuit is opened. The net result is that the current reaching the line changes less abruptly than the current at the teletypewriter sending contacts.

The series capacitors in the telephone lines block the telegraph's direct current from reaching the telephone equipment. The bridge circuit across the telephone circuit, on the drop side of the series capacitors, provides a path to ground for any current unbalance. This prevents crossfire, a condition where telegraph signals sent on one line of a telephone circuit induce voltages sufficient to interfere with telegraph signals on the other wire, or to operate the signaling relays of the telephone circuit.

2.3 Grounds

The earth is often used as one side of an electrical circuit, thus eliminating the necessity of two wires for each circuit. A ground-return circuit is especially important in tactical military communications, because telegraph equipment and teletypewriters are usually simplexed on existing telephone circuits in field installations. In the operation of ground-return teletypewriter circuits, there is probably no one element in the entire system of greater importance than the earth connection. This is so because the earth, considered by itself, has practically no resistance as an electrical conductor. The earth connection is made by driving a metallic ground rod into the earth.

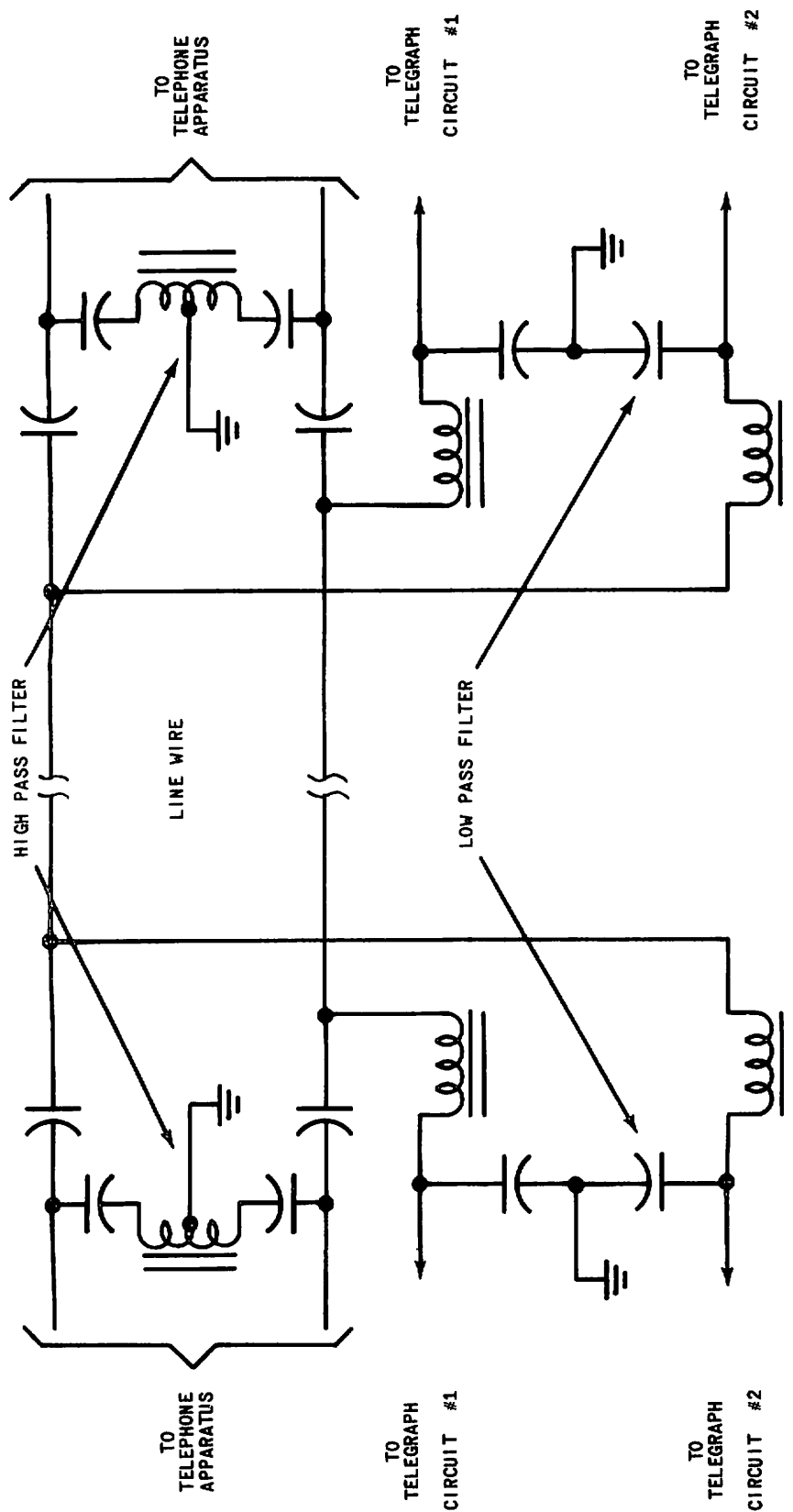
For satisfactory operation of most wire communication circuits using a ground connection, the value of the ground resistance must be kept below prescribed limits. When satisfactory ground resistance cannot be obtained with a single ground rod, additional rods, connected in parallel, will reduce ground resistance; however, no appreciable gain will be obtained by using more than four ground rods. The distance between any two rods should not be less than 10 feet.

2.4 Metallic and Ground-Return Circuits

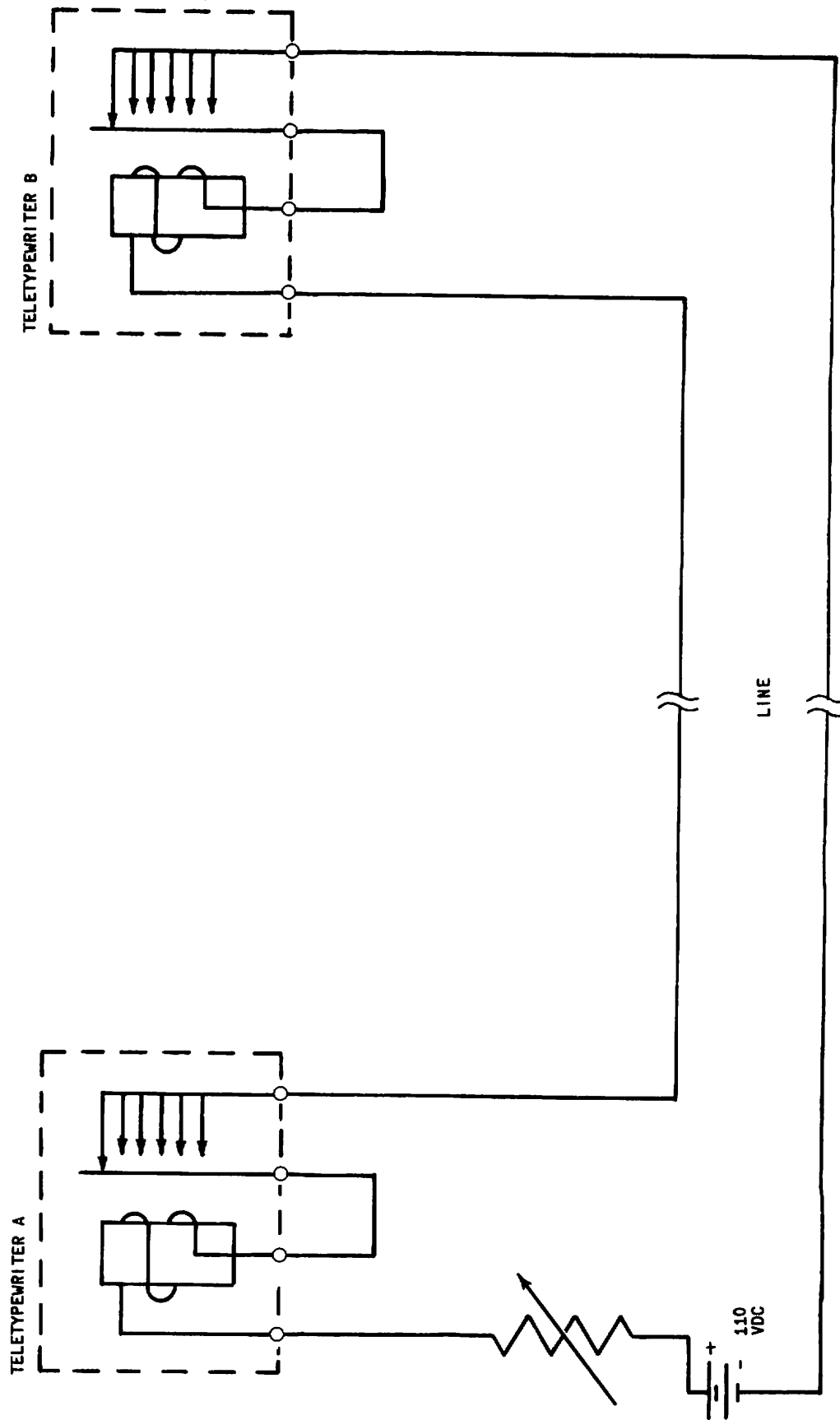
2.4.1 General. Wire circuits are classified as full-metallic or ground-return, according to the electrical paths they follow. An electrical circuit that is completed solely through metallic conductors is a full metallic circuit. In a ground-return circuit, a metallic conductor provides one side of the electrical circuit and the earth the other side.

2.4.2 Full-Metallic Circuit. Figure B-3 shows a full-metallic teletypewriter circuit. Starting at negative battery terminal of teletypewriter A, the circuit flow is as follows: Through a current-limiting resistor, selector magnets, and transmitter contacts of teletypewriter A, through a metallic conductor, teletypewriter B, and the other conductor to the positive battery terminal. Generally, circuits that provide a completely metallic path are more satisfactory than ground-return circuits because there is less leakage, less danger of cross-fire and outside interference.

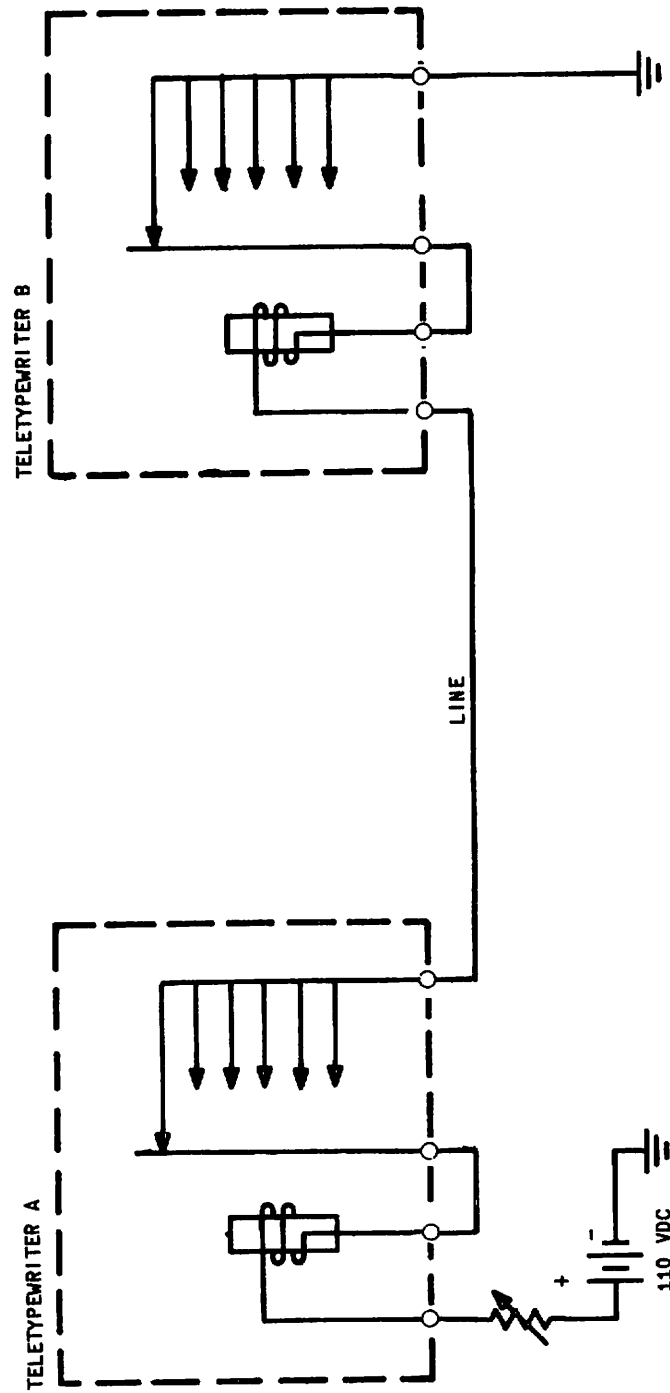
2.4.3 Ground-Return Circuit. Figure B-4 shows a ground-return teletypewriter circuit with two teletypewriters connected in series. The path of the circuit is the same as the full-metallic circuit described in paragraph 2.4.2 above, except that the return path from teletypewriter B to the battery at teletypewriter A is through a ground-return instead of the metallic conductor. In most instances, a ground-return circuit is



TELEGRAPH CIRCUIT ON COMPOSITED TELEPHONE CIRCUIT
FIGURE B-2



FULL-METALLIC TELETYPEWRITER CIRCUIT
FIGURE B-3



GROUND-RETURN TELETYPEWRITER CIRCUIT
FIGURE B-4

more economical because wire is saved by using the earth as one of the conductors. Ground-return circuits also will reduce wire maintenance, and if low-resistance grounds are obtained, there will be lower overall resistance for the circuit than with the completely metallic circuit. However, ground-return systems are susceptible to leakage, constant changes of resistance during wet and dry weather, and induction from power circuits.

3.0 DC TELEGRAPH SYSTEMS

3.1 General

The principal DC telegraph systems used by the Armed Forces are the neutral, the polar, and the polar-potential types. DC telegraph systems, both grounded and metallic, are used extensively; the distance over which they will operate satisfactorily depends on the facilities used or the facilities on which the circuits are superposed, and the signaling speed required. While most long haul telegraph transmission is by means of AC carrier, the telegraph signals at their ultimate terminal, whether sending or receiving, are DC. Transmission over the loops extending from the telegraph central office to the customer's premises is usually by DC. This may also be true for relatively short interoffice lines connecting a major office to tributary offices at outlying points.

3.2 Neutral System

In the neutral telegraph system, transmission is accomplished by sending current over the line for intervals of time corresponding to marking signals, and stopping it for intervals corresponding to spacing signals. Currents are used since the end result of telegraphic communication is the actuation of a teletypewriter magnet, which encodes the mark and space signal elements to select the proper character to be printed on paper or punched on tape.

Figure B-5 illustrates a single transmitting system. To provide the current, a source of power is required. This power supply is referred to as loop battery, or loop supply. The circuit consists of the loop battery, a switch (the teletypewriter or other transmitting devices), and the receiving teletypewriter selector magnet or other receiving device. A resistance is placed in series with the circuit to limit the amount of current flowing when the switch is closed. With the switch closed, current flows through the loop and the receiving teletypewriter selector magnet is energized; this is the mark condition. When the switch is open, no current flows; this is the space condition. The wave form of the signal generated by this current is shown in Figure B-5. The rectangular

wave forms are theoretical and do not reflect the sloping curves of the actual pulse transition periods. The current present in the mark condition is, by convention, either 20 or 60 milliamperes (ma). The currents shown are positive (+); however, some systems operate with marking currents of -20 or -60 ma.

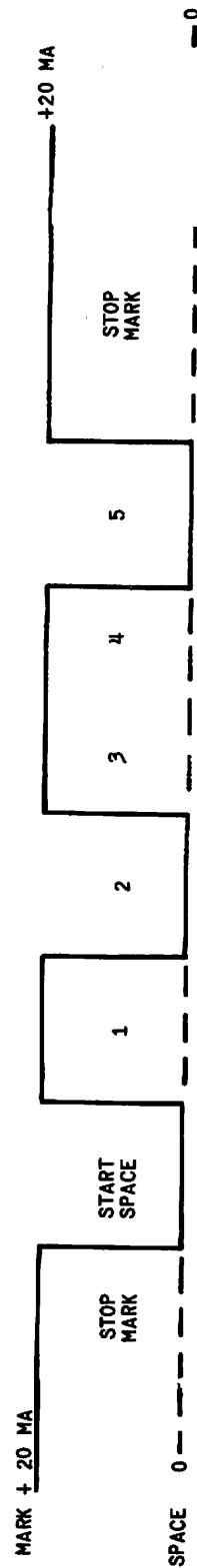
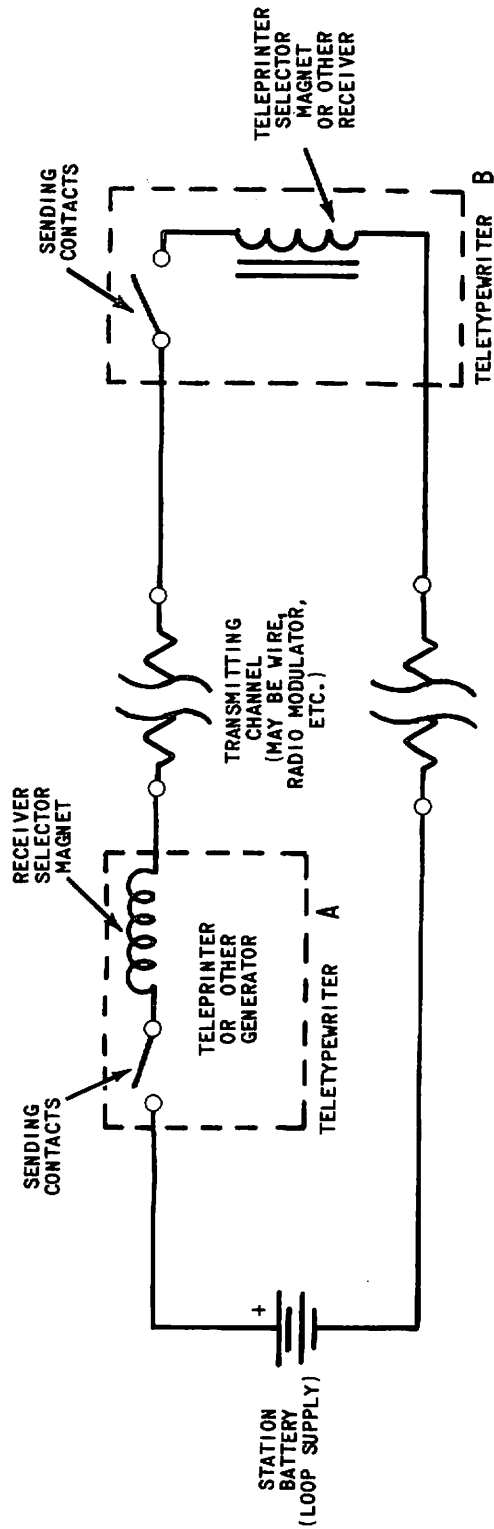
The neutral telegraph system permits transmission of characters in either direction, but is restricted to one direction at a time. The transmitting contact at the receiving end must close the circuit when the sending end is transmitting. It is thus possible for an operator at either end of the circuit to break or interrupt the other operator if the latter is sending. A single neutral system utilizes half-duplex operation—for practical purposes the same as simplex operation—which is defined as an operation that permits the transmission of signals in either direction alternately.

If the duplex operation is required, it is necessary to use two neutral circuits. A system that provides simultaneous transmission in both directions is called a full-duplex operation. Figure B-6 illustrates a circuit employing a full-duplex operation with one teletypewriter at each station. Transmission from A to B is over line 1; transmission from B to A is over line 2. Because the two circuits are separate, there can be simultaneous transmission in both directions. Neutral systems are generally satisfactory when used on short haul services. The transmitted wave shapes are not symmetrical, because of the current on/off design. This condition introduces distortion bias into the loop, which can be tolerated on short lines. However, on long transmission paths, the inductance and capacitance of the loops may cause severe bias distortion.

3.3 Polar System

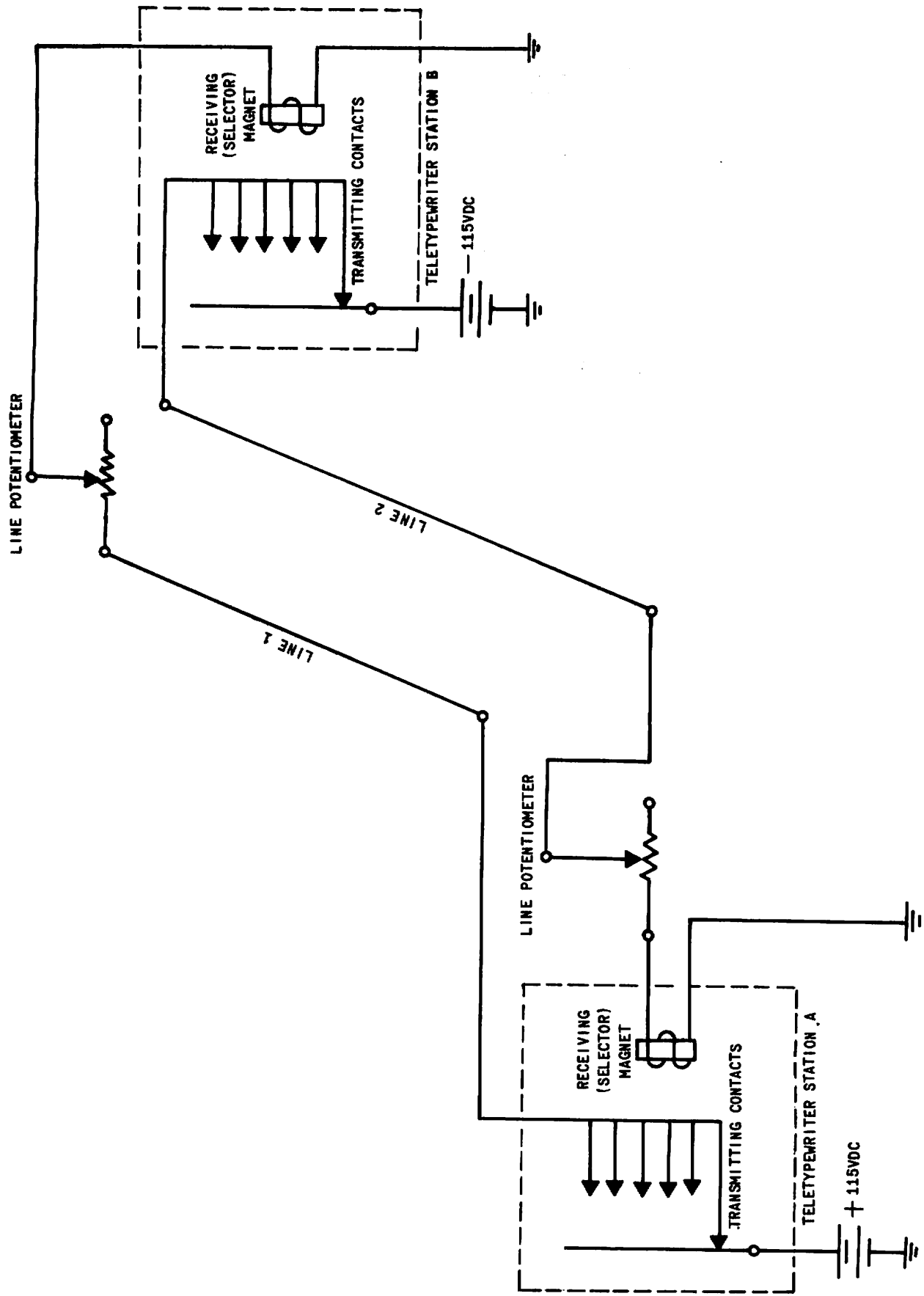
Figure B-7 schematic shows the elementary principles of operation of the one-way polar system. It differs from the neutral system in that a current is present on the line for both the space and mark conditions. Determination of polarity at the receiving end to distinguish the mark and space condition is inherently more sensitive and more immune to interference than in the neutral system.

The teletypewriter A transmits neutral signals into the A polar relay, which relays the signal to the line as polar signals. The B polar receiving relay accepts the polar signals from the line and relays to the local teletypewriter B as neutral signals. At the sending station, the polar sending relay provides two sources of DC current, one of each polarity. When signals are being transmitted for the marking condition, one polarity of voltage is connected to the line, and for the spacing condition, the opposite polarity of the same magnitude



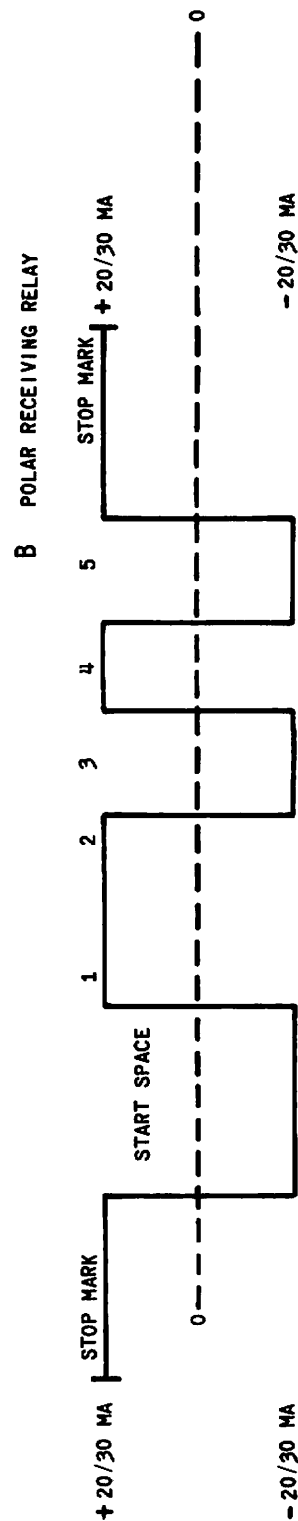
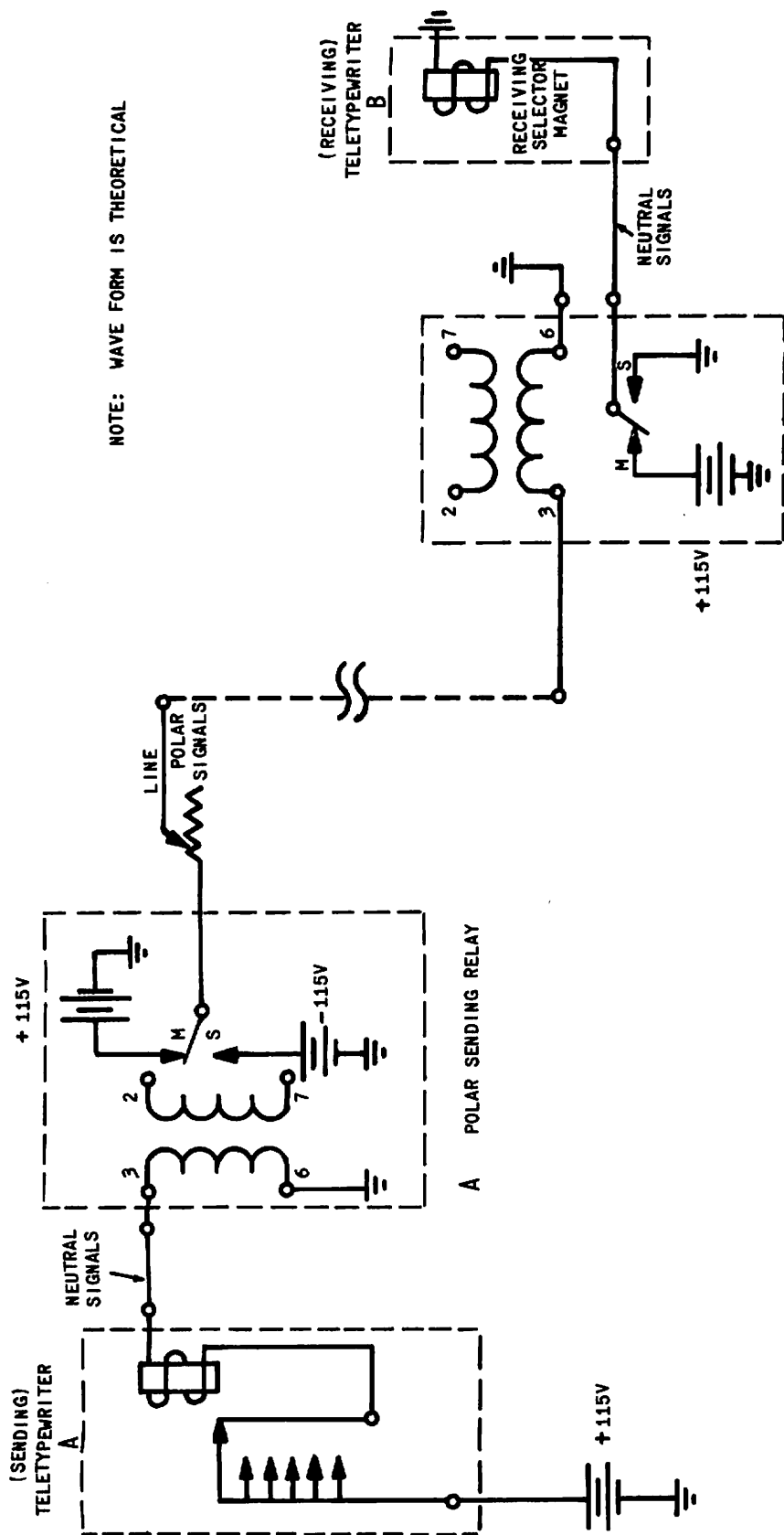
NOTE: WAVE FORM IS THEORETICAL

(Used by permission of Stelma, Incorporated, Stamford, Conn.)
ELEMENTARY NEUTRAL TELEGRAPH SYSTEM AND SIGNALS
FIGURE B-5



B-11

NEUTRAL FULL-DUPLEX OPERATION
FIGURE B-6



ELEMENTARY POLAR ONE-WAY TELEGRAPH SYSTEM AND SIGNALS
FIGURE B-7

is connected to the line. Instead of the current being reduced to zero for the spacing condition as in the neutral system, it is reversed, resulting in a symmetrical wave with respect to marking and spacing signals. The theoretical waveform of a polar signal is shown in Figure B-7. The mark condition is represented by a positive value of current, and the space condition as a negative current. The current magnitude is usually 20 or 30 milliamperes; positive mark is standard, but may vary among systems.

With polar operation, the probability of bias distortion is substantially reduced over neutral operation, as the marking and spacing current waveshapes are identical. The polar system is the most stable of the ground telegraph systems; it is especially valuable for teletypewriter operation, because no readjustments are required at the receiving station to compensate for circuit changes. The chief disadvantage is that in its elementary form, it permits only one-way transmission of messages, whereas all other DC telegraph transmission systems provide half-duplex service. Notwithstanding this disadvantage, the one-way polar system is used extensively, particularly for teletypewriter service to outlying points. It is used commercially in single-section service on open wire over distances of about 200 or 300 miles, and in cable up to about 100 miles, to connect one or more outlying stations to a telegraph system. It may be used in a similar manner for one-way manual service, using a polar relay to repeat the local station. When full-duplex service is required, two one-way polar systems may be used. (See Figure B-8.)

Another scheme for full duplex polar operation is called differential duplex. This plan involves polar sending and receiving relays at each terminal. Figure B-9 depicts schematically terminal differential duplex sets arranged for full duplex over a single-wire ground return circuit. At each terminal, the receiving relay has two equal windings, one being connected to the real line and the other "differentially" to the artificial line circuit. Sending current from the sending loop divides at the apex of the receiving relay windings and flows equally in the real and in the artificial line circuits, assuming these are balanced. Since the receiving relay windings are differentially connected, the station receiving relay is not affected by this current flow. However, current from station B does operate the receiving relay at station A, since it flows through the windings of this relay in a series aiding relation from the line through the balanced arms and the artificial line to ground. Similarly, the receiving relay operates at station B from incoming line current from station A. Under these conditions, full duplex operation is attained.

The transmission possibilities of the one-way polar system, like the neutral system, depend on the facilities

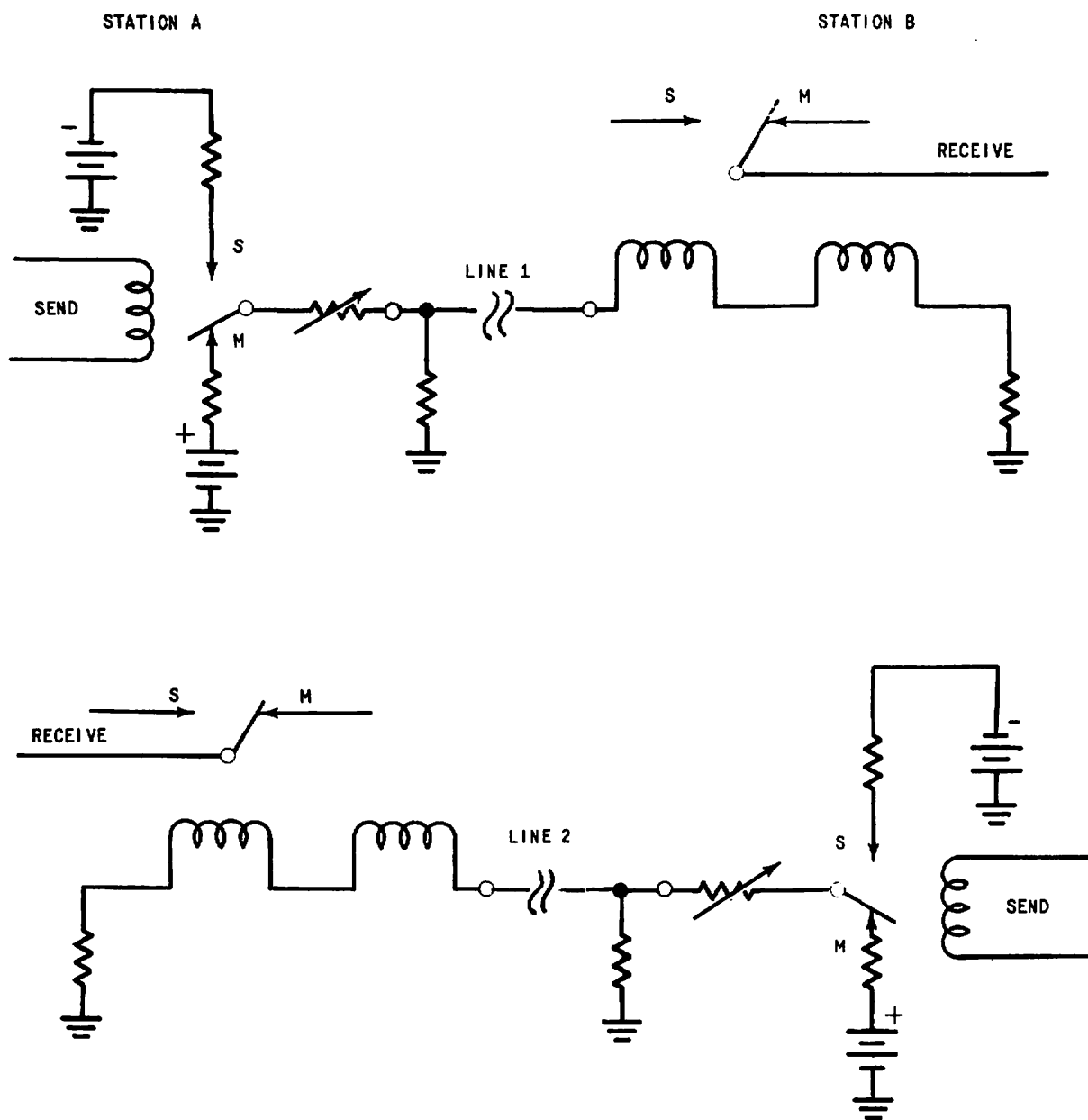
used, or the facilities on which the telegraph circuit is superposed. In commercial operation, it is possible to obtain satisfactory transmission at 60 wpm over single sections of average-grade, 0.104-inch, open-wire circuits, up to about 300 miles. If intermediate composite sets are in the circuit, or if finer gage wire is used, this distance will be less. In cable circuits, where noise considerations (thump and crossfire) permit, the polar system should provide satisfactory 60-wpm transmission over composited 13- or 16-gage circuits (or simplex 19-gage circuits), up to about 100 miles. Like all other grounded telegraph systems, transmission will be affected by earth potentials, crossfire, and power induction.

3.4 Polar Relays

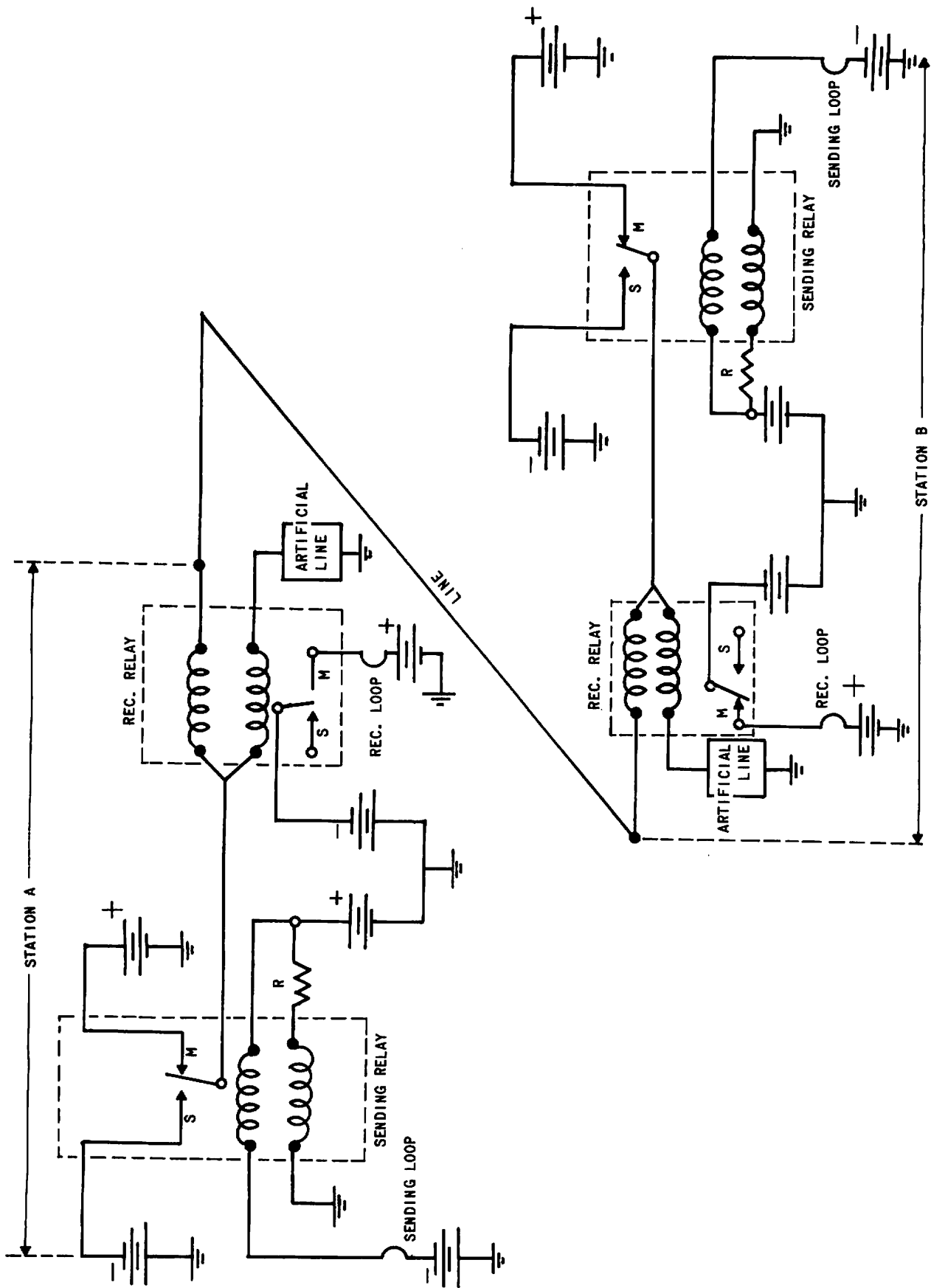
3.4.1 Description of Polar Relays. In polar operation, mark and space signals are formed by reversing the direction of the current flow over the line. When this type of operation is employed, polar relays are required in the circuit. The polar relay will operate to the mark contact when the current flows through it in one direction and will operate to the space contact when the direction of the current flow through it is reversed.

Basically, a polar relay consists of a permanent horseshoe magnet with the armature of the relay suspended between the pole pieces and the windings of the relay wound around the armature. When current flows through the winding in a direction to cause the lines of force in the armature to flow upward, making the top a north pole, the armature will be attracted to the south pole permanent magnet pole piece. If the current flow is reversed, the polarity of the armature is reversed, making the top a south pole that will be attracted by the spacing pole piece (north). When no current flows in the winding, the armature is centered between the two pole pieces, since it has no polarity and the attraction of both pole pieces is equal. Figure B-10 shows the essential features of a WECO 255-type polar relay. A schematic circuit of a polar-type relay is shown in Figure B-11. Usually the bias winding is opened, and only the line winding is used for polar operation. When there is neutral input into the polar relay, the bias winding is required in conjunction with the line winding.

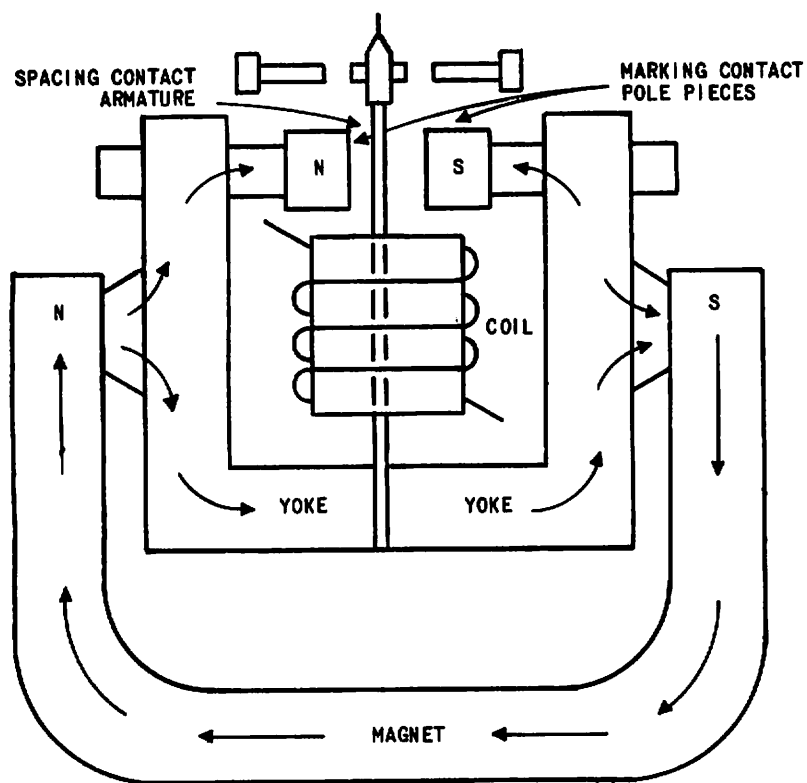
Solid-state electronic relays are now manufactured by several electronic firms and are designed to replace the electromechanical polar relays presently in general use. The electronic relays provide for neutral or polar input/output. The absence of any moving parts, no mechanical adjustments, and no contacts to burn out assure continual and reliable operation. A representative product specifies operating rates of up to 2000-baud neutral and up to 1000-baud polar, with less than 3 percent distortion.



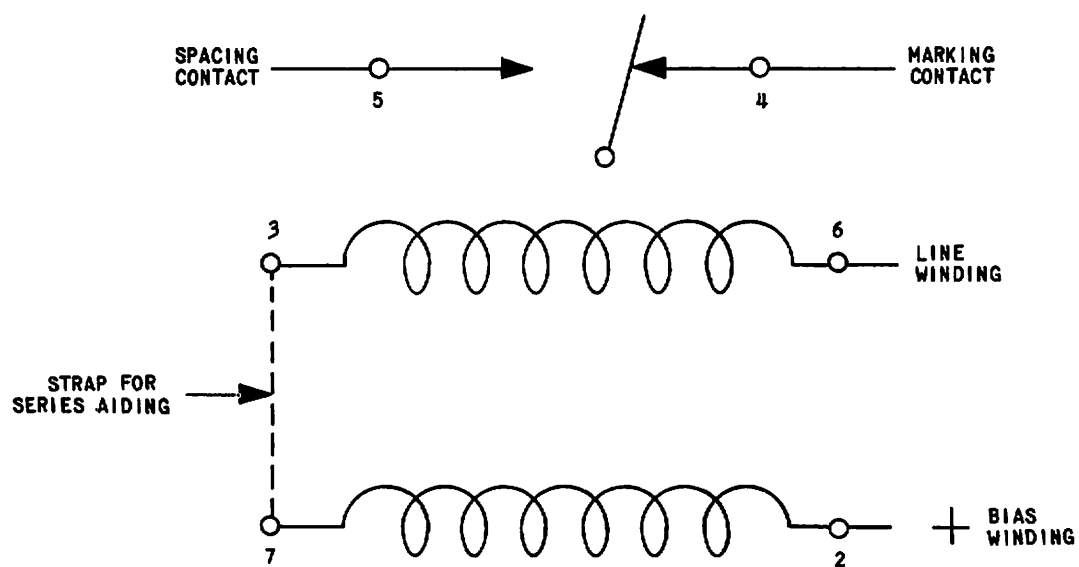
**TWO-PATH POLAR TELEGRAPH SYSTEM
FIGURE B-8**



DIFFERENTIAL DUPLEX TERMINAL SETS ARRANGED FOR FULL DUPLEX SERVICE
FIGURE B-9



ESSENTIAL FEATURES OF THE 215- OR 255-TYPE POLAR RELAY
FIGURE B-10



SCHEMATIC CIRCUIT OF THE 215- OR 255-TYPE RELAY (POLAR OPERATION)
FIGURE B-11

Polar relays are more sensitive receiving units than are the selector magnets in teletypewriters; therefore, they allow greater operating distance between teletypewriters. Polar relays are the principal components of DC repeaters and DC loop-circuits in carrier-telegraph terminals.

3.4.2 Use in Combined Polar and Neutral Operation. A circuit using one-way polar operation is shown in Figure B-12. The teletypewriter transmits neutral signals into the A polar relay, which relays the signals to the line as polar signals. The B polar relay accepts the polar signals and relays them to the local circuit as neutral signals.

3.4.3 Polar Relay Operation on Neutral Signals. When the polar relay is used as a line relay on a local 60-ma neutral circuit (Relay A, Figure B-11), the bias (2-7) winding is locally supplied with 30 ma of steady current in a direction that causes the armature to be held to the spacing contacts. When a marking pulse is transmitted, current of 60 ma flows from the positive battery at the transmitter contacts, through the line potentiometer, the 3-6 winding of the polar relay to ground, and returns through ground. The magnetic field induced by the 60 ma in the line (3-6) winding overcomes the magnetic field induced by the 30 ma of locally supplied current in the bias winding. This causes the armature to move to the marking (M) contact under the influence of an effective magnetic force resulting from 30 ma of current. When a spacing impulse is sent, the transmitting contacts at the teletypewriter open the line circuit, and no current flows in the 3-6 winding. The armature of the polar relay is moved to the spacing (S) contact by the 30 ma of current in the bias winding.

3.4.4 Polar Relay Operation on Polar Signals. When the A polar relay is on the mark contact, current flows from the positive terminal of the battery, through the mark contact, the adjustable current potentiometer, the line, the 6-3 winding of the B polar relay to ground, and returns through ground. The current is in a direction to operate the B polar relay to the mark contact. When the A polar relay is on the space contact, the negative terminal of the battery is applied to the lines and the B polar relay is reversed, causing the relay to operate to the space contact. The polar relay operates on reversals of current flow; therefore, no bias current is necessary at the B polar relay. The signals in the local circuit are neutral. Current flows through the receiving selector magnet when the B polar relay is on the mark contact; no current flows in the local circuit when the relay is on the space contact.

3.5 "POLARENTIAL" System

The POLARENTIAL system of transmission is a combination of the polar and differential-duplex methods. In a differential-duplex (polar duplex) system, an impedance balance is maintained at each end so that the receiving relay is unaffected by the send signals. This allows for simultaneous transmission in both directions over one wire (full-duplex operation).

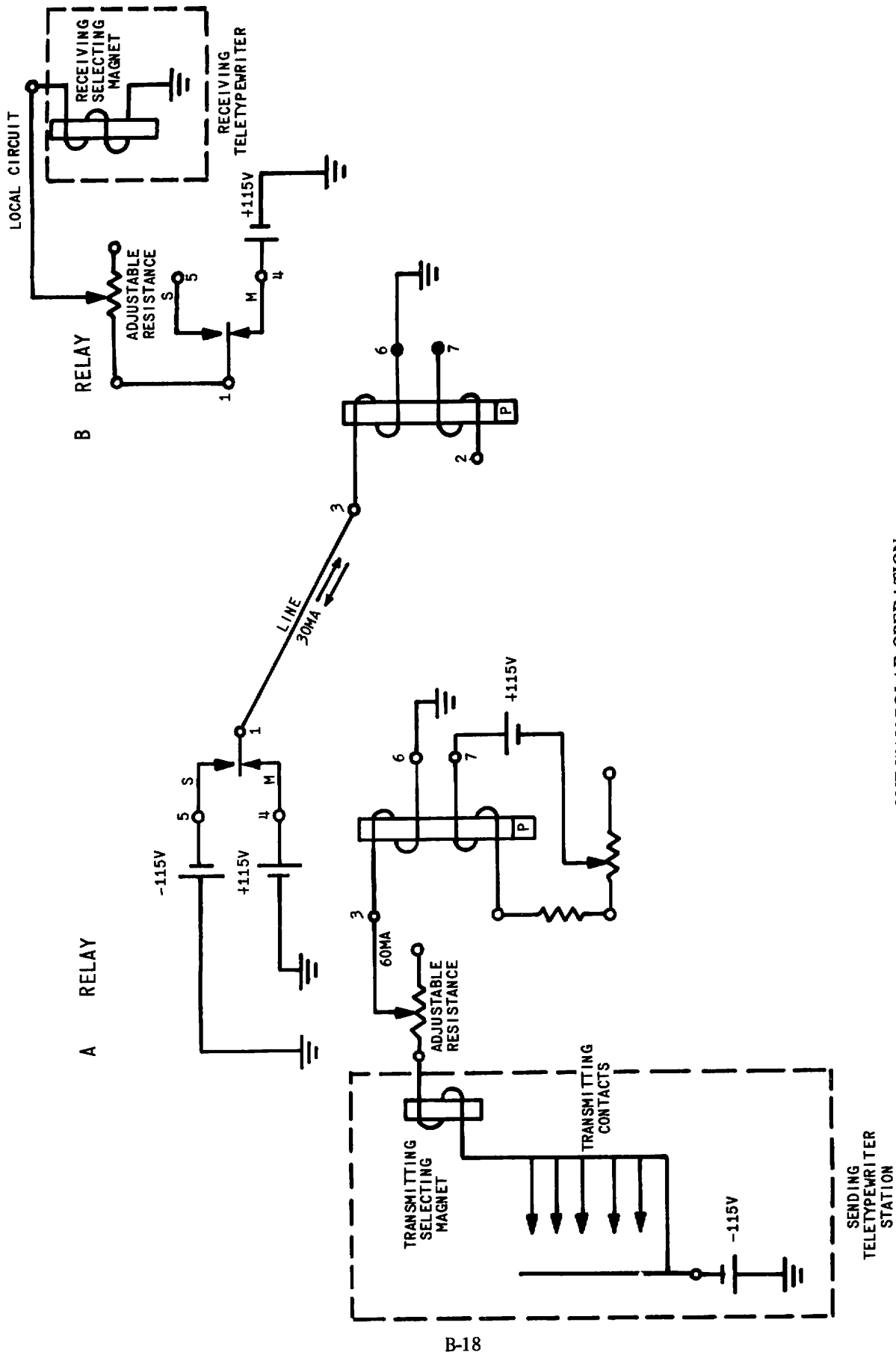
The advantage of the POLARENTIAL system is that the combined effect is the equivalent of polar operation in both directions, using one wire. The two types of operation used by the commercial agencies are type A and type B POLARENTIAL operation. The type A POLARENTIAL system is most useful in circuits where line resistance variations are a controlling factor. The advantage of the type B system is that the circuit is self-compensating to a considerable extent for line leakage; consequently, it is frequently used on open-wire circuits where weather conditions cause considerable variations in the amount of line leakage. These two special types of grounded telegraph systems are frequently used for furnishing service from central offices to subscribers on long loops to outlying points. The POLARENTIAL system provides half-duplex service by means of polar transmission from the central office out, and self-compensating differential duplex transmission from outlying points to the central office. Thus, the advantages of polar transmission are secured and, at the same time, the equipment arrangements at the subscriber's outlying point are relatively simple.

Figure B-13 shows the basic features of a type B POLARENTIAL circuit. When transmission is from A to B, polar-type sending is employed. When transmission of signal is from B to A, there is no reversal of line current, and the line current for spacing is three times that for marking since 65 volts is applied to the line circuit for marking and 195 volts for spacing.

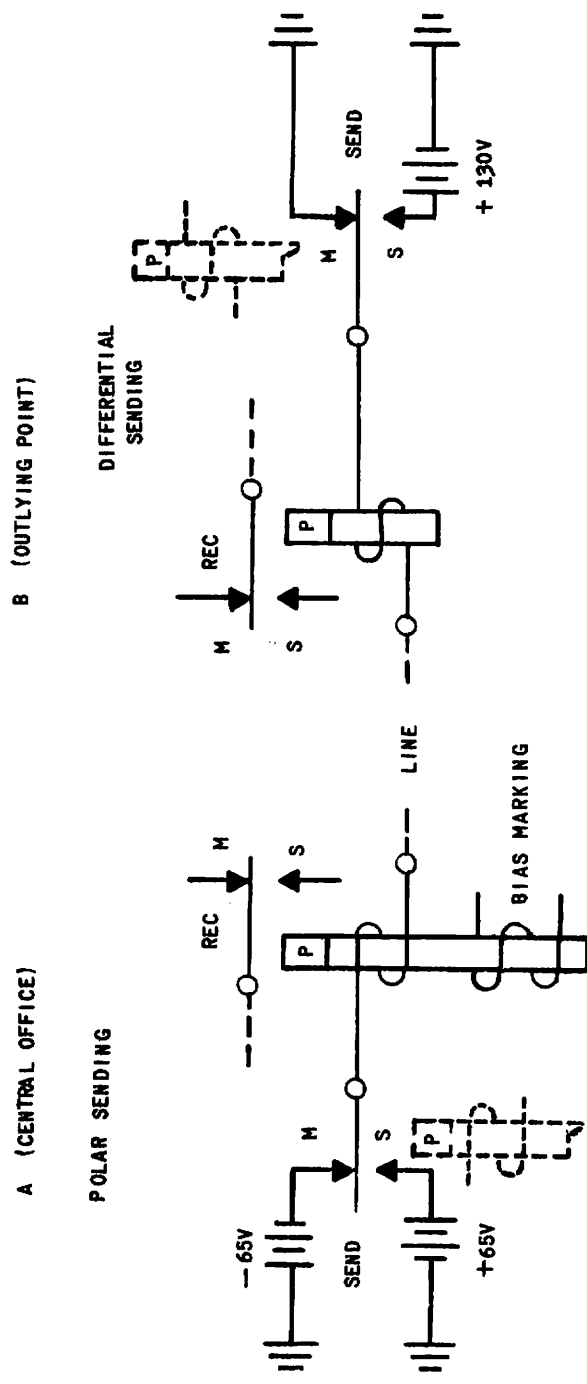
When station B (Send) is in the marking position, line current flows from B to A. Since the bias marking current at station A (Receive) is of opposite polarity and twice the magnitude of the line current, the receive contacts at station A are held in the marking position.

When station B (Send) is in the space position, line current still flows from B to A; however, line current is now twice the magnitude of the bias marking current, and the receive relay at A is moved to spacing. Therefore, the marking and spacing effects on the receiving relay at A are equal, and the reception is equivalent to polar operation.

When leakage occurs on the line, there is a reduction in the spacing current from B, and the bias current is



ONE-WAY POLAR OPERATION
FIGURE B-12



POLARENTIAL TELEGRAPH CIRCUIT (TYPE B)
FIGURE B-13

adjusted to compensate for this reduction in spacing current. These two effects cancel each other so that no bias distortion results from the line leakage.

4.0 CARRIER TELEGRAPH SYSTEMS

4.1 General Theory

In carrier telegraph systems, an alternating current is provided for each channel. This carrier is modulated at the sending end by operation of the telegraph sending equipment, which originates signals at its contacts in DC form. At the distant end, the carrier signals are demodulated and restored to DC form for actuation of the telegraph receiving instrument. Most systems use carrier in the voice-frequency (VF) range, but frequencies above this range are used in some systems. The VF carrier systems can operate over any good telephone-type circuit, wire, or radio.

4.2 Types of Modulation

Two forms of modulation are in general use: amplitude modulation (AM) and frequency shift keying (FSK); the latter is an elementary form of frequency modulation (FM).

Amplitude modulation is illustrated in Figure B-14 in which the carrier is keyed "on" for marks and "off" for spaces. In this tone/no tone arrangement, the carrier current supplied by an oscillator is connected to the line via bandpass channel filters. In two-tone (AM) modulation, two signals of different audio frequencies are used for a single traffic channel. One tone transmits the mark condition, and the other tone transmits the space condition. In the two-tone method, each tone is produced by a separate oscillator. For example, in a particular channel, the mark tone may be a frequency of 425 cps, while the space tone would be 595 cps, thus employing a separation of 170 cps.

In the frequency shift method (Figure B-15), the carrier is shifted between one frequency representing mark pulses, and a second frequency representing space pulses. The two frequencies are symmetrically disposed with respect to the midband or nominal carrier frequency, e.g.:

Marking frequency	= 382.5 cps
Midband carrier frequency	= 425.0 cps
Spacing frequency	= 467.5 cps

In comparing the AM and FSK methods of modulation, the AM method allows noise and interference to appear as additional variations with the signal in modulating the amplitude of the carrier wave. When these variations approach or exceed the variation caused by

the keyed intelligence, the signal is blanked out by the interference. As variations in signal amplitude as well as noise variations have little effect on changes in frequency when the intelligence variations are impressed upon the carrier frequency (FSK modulation), the effects of noise and interference are practically eliminated.

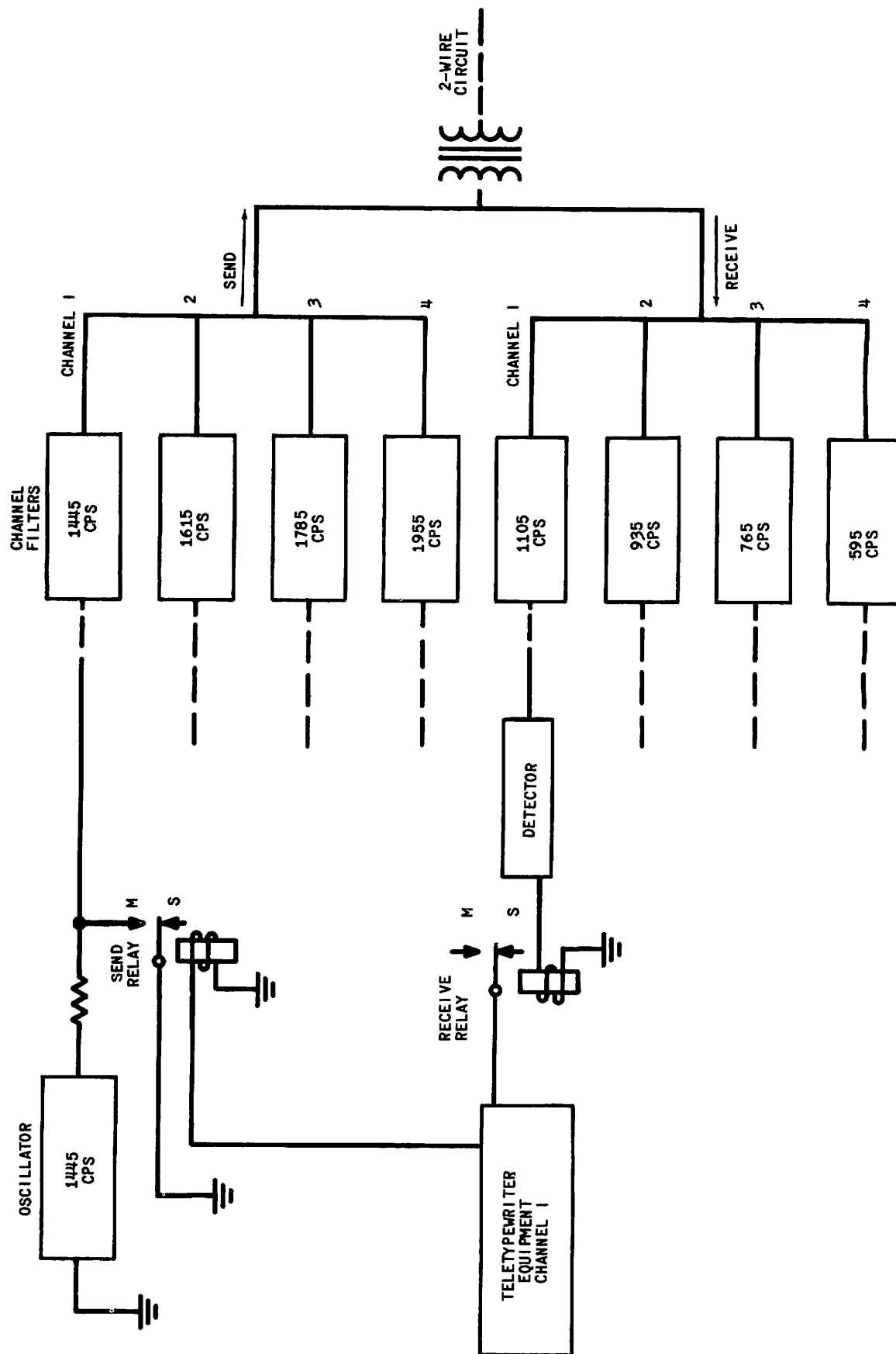
The AM method is analogous to neutral operation in DC circuits and similarly subject to effects of signal level variations and interference. It is most suitable for modulating an ultra-high frequency (UHF) radio carrier. The frequency shift method will operate with little bias through wide changes in circuit attenuation and is affected less by interference. However, it requires close frequency stabilization to prevent bias. The frequency shift system is adaptable for use on circuits such as high frequency (HF) radio circuits that are subject to severe fading.

4.3 Multichannel Carrier Telegraph

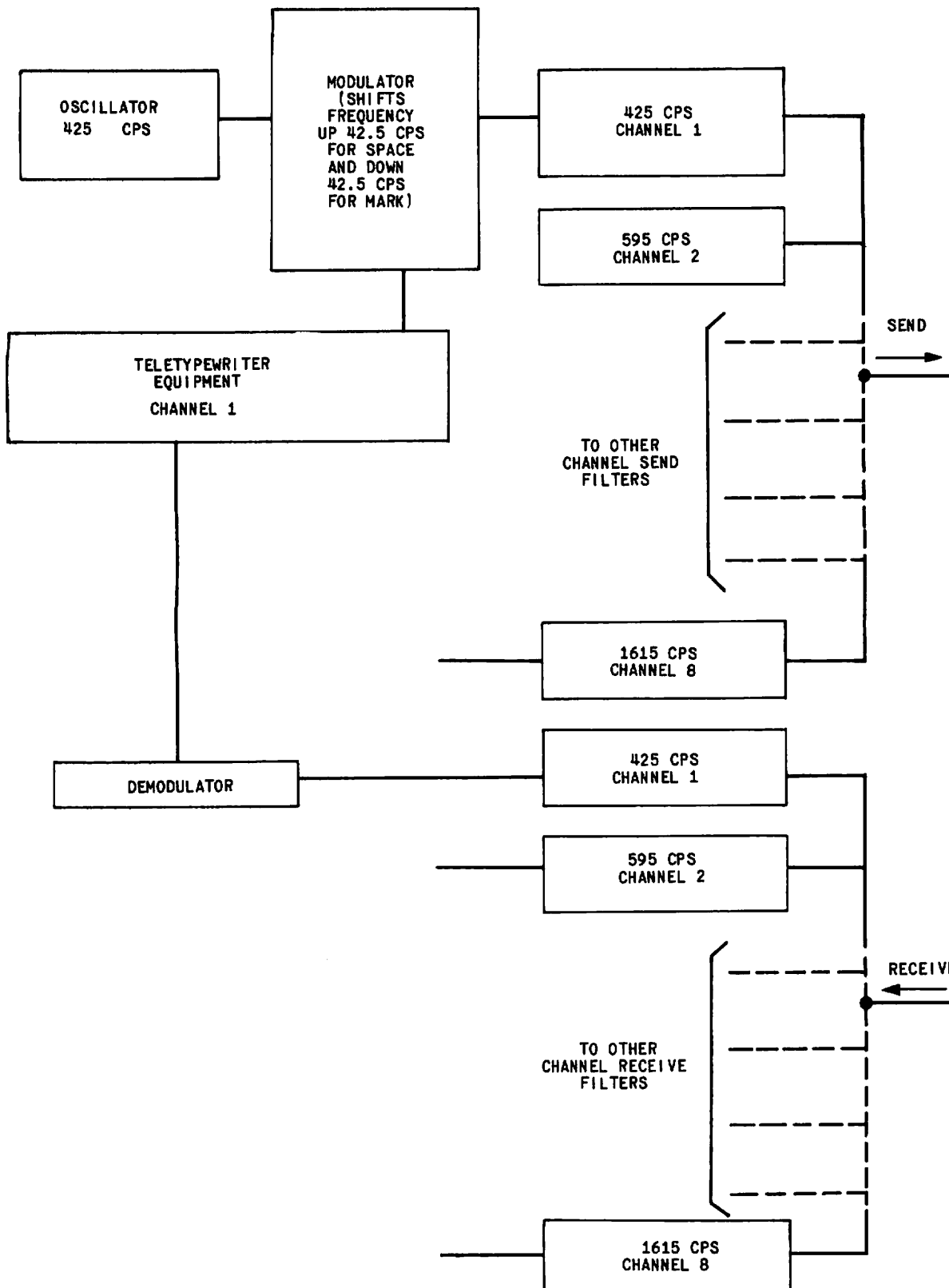
The most widely used method for deriving telegraph circuits on land lines and radio is the frequency-division-multiplex (FDM) telegraph system. By FDM methods, as many as 24 telegraph circuits may be operated simultaneously over one telephone circuit. The basic principle employed is that a different pair of audio frequencies is used for each telegraph channel, and the channels are separated at the sending and receiving ends by suitable bandpass filters. Thus, the bandwidth of the telephone is effectively divided into a number of smaller bands, each suitable for telegraph signaling. The most commonly used channel spacing is 170 cps which provides a 16-channel FDM in a nominal 3000-cps voice frequency band. The keying speeds are up to 90 baud. By shortening the channel spacing to 120 cps, 24 telegraph channels can be accommodated in the normal audio band. The maximum keying speed is then reduced to 75 baud.

The carrier frequencies used for FDM systems are chosen to lie within the pass band of a good quality telephone circuit. The telephone circuits employed may be provided by open wire, underground cable, or radio link. The circuit itself may be a channel in a telephone carrier group. The FDM telegraph systems employ essentially the same type of line plant as normal telephone circuits. The merits of FDM working may be summarized as follows:

- (a) The VF telegraph signals may be amplified by standard telephone amplifiers.
- (b) The telephone line and amplifiers cause little distortion to the telegraph signals.
- (c) The same line plant and radio link equipment is used for FDM telegraph circuits as for telephone cir-



ELEMENTS OF AN AM CARRIER TELEGRAPH SYSTEM
FIGURE B-14



ELEMENTS OF A MULTICHANNEL FSK CARRIER TELEGRAPH SYSTEM
FIGURE B-15

cuits. This enables telephone and telegraph transmission systems to be completely integrated.

The basic functions of the FDM telegraph equipment can be described as follows:

(a) In the transmit direction: accept DC telegraph signals for each of several telegraph circuits and convert them to corresponding audio tones.

(b) To combine the several audio frequency tones into a common output signal suitable for transmission through an audio frequency channel.

(c) In the receive direction: accept the audio frequency channel and separate the channel into audio frequency tones for each telegraph circuit.

(d) To convert the audio frequency tones into DC telegraph signals.

These various functions for an 18-telegraph channel system are shown diagrammatically in Figure B-16.

Another method of multiplexing two or more apparently simultaneous channels from a given frequency spectrum within a transmission medium is the time-division-multiplexing system. The entire spectrum is assigned to different channels at different times, usually at regular intervals by automatic distribution. The medium is connected in rapid succession to a number of transmitting and receiving instruments at each end by means of synchronized distributors. Each low speed channel is thus assigned exclusive use of the spectrum for a short period (time division) during which elements of a signal combination can be sent sequentially at high speed. In general, time-division-multiplex systems use pulse transmission. The multiplex pulse train may be considered to be the interleaved pulse trains of the individual channels. The distributor at each end of the system must be accurately synchronized to ensure that the corresponding transmitting and receiving equipments for each channel are connected at the correct time. The aggregate traffic capacity of the line is equal to that of the line if it were used as a single high speed channel.

4.4 Single Channel VF Telegraph

Single channel voice-frequency (VF) telegraph is often used on telegraph loops and for short distances on lines or trunks. A common use is a single channel radio teletypewriter circuit as shown in Figure B-17. Modulation may be two-tone AM on ultra-high frequencies or FSK in the high frequency radio band. When FSK methods are used for the telegraph transmission, no carrier is applied when the circuit is idle. Sometimes a pair of wires or a telephone channel is used solely for such a telegraph channel. In other cases, the pair of wires or telephone channel may also be used at the same time for a telephone circuit. The method is called speech-plus-half duplex and is accomplished by means of filters that

remove a 500-cycle band from the speech channel for use by the telegraph channel. The removal of this band degrades the speech channel by a 5-db loss.

4.5 Diversity Operation

On long HF radio circuits, diversity operation is usually required to overcome fading, which commonly causes large variations in the received signal strength. In a diversity system, two or three virtually independent sets of signals carrying the same intelligence are made available to operate the receiving instruments. The signals are combined at the radio receiving station in such a manner that, at any instant, the better signal is automatically selected to operate the end instruments.

In space diversity, signals are sent from a single distant transmitter to actuate two radio receivers having individual antennas separated by a distance equal to several wavelengths. With this system the received signals seldom fade deeply in both receivers simultaneously.

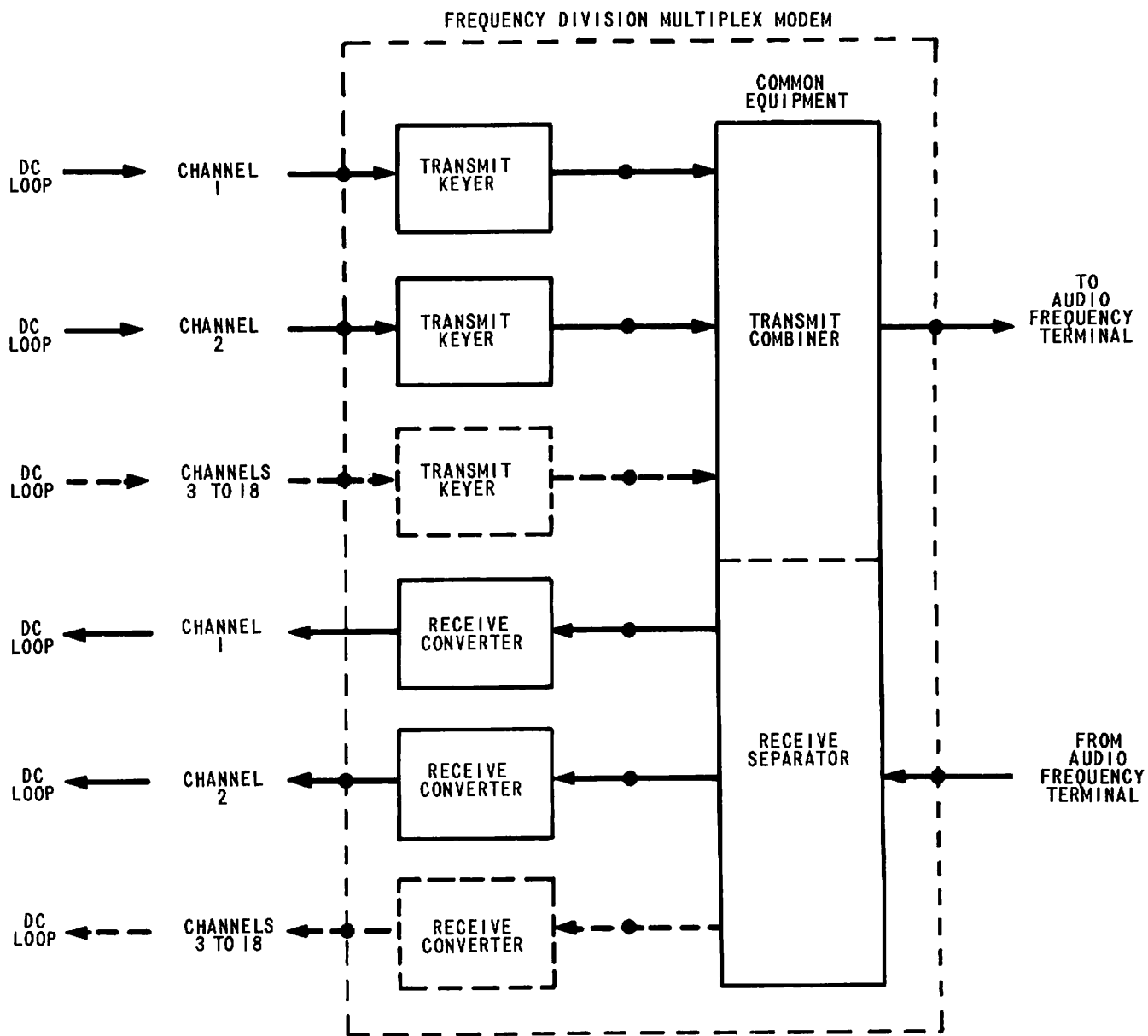
In frequency diversity, each signal (mark or space) is sent simultaneously at two frequencies differing by at least a few hundred cycles, and received on a single radio receiver. Both signal frequencies seldom have the same fade characteristics at the same time, and the selection of the better signal to operate the receiving teletypewriter equipment results in an improvement comparable to that obtained with space diversity. Frequency diversity is less desirable than space diversity, because it requires more space in the frequency spectrum. However, space diversity requires duplicate antennas and receivers.

4.6 HF Multichannel Radio Long-Haul Systems

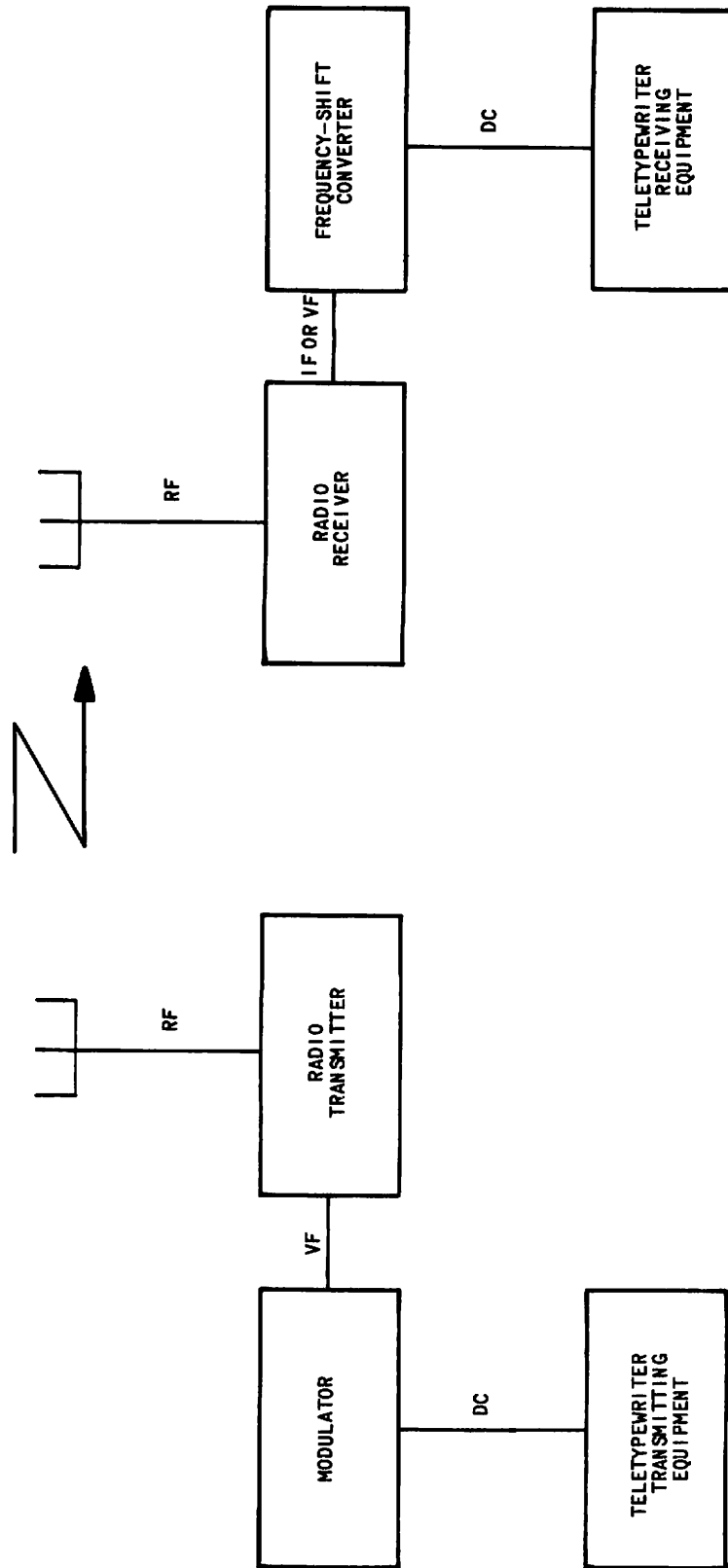
4.6.1 *General.* The military worldwide network utilizes landlines, cables, wideband microwave radio relay, forward propagation ionospheric scatter (FPIS), forward propagation tropospheric scatter (FPTS), and HF radio as a transmission media. HF radio circuits carry an appreciable amount of long-haul teletype and voice traffic. Since most of the techniques of multichannel radio telegraph occur at a radio switching center, the components of a HF radio relay center are discussed in some detail in the following paragraphs.

The radio-frequency spectrum congestion is the overriding constraint for the HF medium. Such factors as radio-frequency assignments, authorized powers, and emissions are the boundaries within which the system must operate.

The majority of long-haul military HF network circuits provide either four teletype multiplex channels or four VF channels assigned to one facsimile, two telephone, plus 16 teletype channels derived from one VF channel.



FREQUENCY DIVISION MULTIPLEX FUNCTIONAL BLOCK DIAGRAM
FIGURE B-16



B-25

SINGLE-CHANNEL FSK RADIO TELETYPEWRITER CIRCUIT
FIGURE B-17

4.6.2 HF Long-Haul System Block Diagram. Figure B-18 is a functional diagram of a major radio facility showing the routing of teletypewriter and other communication signals from end instruments outward and inward. Depicted are the functional aspects of a communication relay center with the associated remote transmitter and receiver radio sites. The diagram delineates an HF independent sideband (ISB) system. These systems usually are assigned high power (up to 50 kw), and cover distances of up to 4200 nautical miles, with an average distance of about 2000 nautical miles. The assigned frequencies are distributed throughout the HF band (3 to 30 mc).

The lettered blocks (A-O) within the functional diagram, Figure B-18, perform specific functions, as described below.

4.6.2.1 Blocks A, B, and C

These blocks form the area of terminal or user equipment.

(a) Block A includes facsimile recorders and transmitters. This equipment prints or transmits pictorial information, usually weather maps.

(b) Block B includes the teletype and low-speed data user equipments, such as teleprinters, reperforators, transmitter distributors, and card punch devices. Some, or all, of this equipment may be found at a base or station message center.

(c) Block C includes telephone (voice) user instruments. A representative instrument would be the Western Electric type 500 handset.

4.6.2.2 Blocks D, E, and F

The area within blocks D, E, and F represents the routing and control functions of the circuit. Signal processing may be required to bring signals to or from the user equipment in areas A, B, and C; particularly teletype DC output, which usually is converted to audio tone for transmission over wire or microwave links. The audio outputs frequently require amplification if points A to D or C to F are distant from one another. Blocks D, E, and F are usually found in a Communications Relay Center (CRC).

(a) The function of facsimile switching (presently accomplished manually) and the processing of the AM facsimile signal for transmission over an HF radio system are both performed in block D. It may also serve to permit conversion of a facsimile signal received over an HF radio system for transmission over wire or microwave systems.

(b) Block E contains teletype, low-speed data switching equipment and facilities to monitor and control signals associated with this subsystem. Areas of

consideration in this block are the Channel Technical Control Facility (CTCF), automatic switching centers (Plan 55, AN/FGC-30, and 82-B-1 systems), and torn-tape systems.

(c) Block F provides routing and control of voice circuits. Presently, this is accomplished by manual patching. Two-wire to 4-wire devices are found in block F to provide connection of the 2-wire telephone line from C to the 4-wire side. These devices are telephone terminals, which may control, limit, amplify, compress, or expand voice signals from blocks L-N, and provide similar control to signals to blocks K-M.

4.6.2.3 Block G

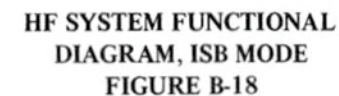
The binary signals from Block E pass through G, the crypto block. Block G processes these signals in both the send and receive directions. It should be noted that block G may also appear between blocks B and E, thus performing its function of full duplex link-encryption on that path as well. Functional blocks to the right of G are carried in the transmission subsystem. Included in this subsystem are multiplexing equipment, intersite links, transmitters, receivers, and RF transmission line and antenna facilities.

4.6.2.4 Block H

Signals leaving G to the right are binary and need further processing to be passed over a radio system. This is accomplished in block H by converting DC binary loops to audio tones. Carrier techniques are employed in this block, which permit up to 16 DC loops to be multiplexed on one nominal 3-kc voice channel. Block H also performs the reverse demultiplex function, converting audio tones from the receiver site to equivalent DC binary information which passes to G. Low-speed data (up to 75 bauds per channel) may be handled in a similar manner.

4.6.2.5 Blocks I and J

Blocks I and J, part of the transmission subsystem, relate to the intersite relay network. This network provides the facility to pass the various information channels (telephone, FM facsimile, and bit stream in audio tones) between the communication relay center and the remote sites. Block I contains VF multiplexing equipment. It combines, or multiplexes, the four nominal VF channels to form the baseband frequencies, which modulate the microwave transmitter in block J. In the reverse direction, block J represents the microwave receiver, delivering the baseband frequencies to I. Block I, in the receiving direction, demultiplexes the baseband to VF channels. These are, in turn, passed to their respective blocks D, F, and H.



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4.6.2.6 Block K

At the HF transmitter site, block K contains another multiplex equipment, combining two nominal 3-kc channels to form a 6-kc channel. Normally, a transmitter in block M requires two such multiplexers, one for each sideband.

4.6.2.7 Block M

There are two blocks labeled M (HF transmitter). The separation was made to illustrate the two ISB transmit systems (pilot carrier and synthesizer methods). The major difference is in the method of carrier frequency generation. ISB transmitters of older design had a carrier frequency stability in the order of 3 parts in 10^6 per day. This frequency characteristic required Automatic Frequency Control (AFC) on the receiving end to ensure proper reception of composite audio tones. In this system, the AFC in the receiving system is actuated by a pilot carrier frequency suppressed 20 db below the reference level (peak envelope power) of the modulated signals. With no AFC, the poor stability would cause intolerable bias distortion in the resulting DC loops. This distortion is due to translation of the demodulated audio signal by an amount equal to the RF carrier frequency error.

(a) Modern ISB transmitters have improved frequency generation with a stability of 1 part in 10^8 per day. This stability permits elimination of AFC circuitry, and permits operation with full carrier suppression. Often these transmitters have a separate external RF generator, which is referred to as a synthesizer. This permits frequency control, with 100-cps incremental tuning throughout the tuning range.

(b) The transmitters in both transmit systems accept two 6-kc audio channels; one channel is transmitted in the upper sideband, the other in the lower sideband. The information capability of this system depends on path conditions and service required. A fully loaded system normally assigns two voice channels, one facsimile channel, and one FDM channel containing composite tones to one RF circuit.

4.6.2.8 Block L

Block L contains the demultiplexers. Each unit accepts a 6-kc audio band from the receive system, and delivers two 3-kc channels to the intersite link.

4.6.2.9 Block N

Block N is the receiver system block. Two basic receivers are employed on a high frequency radio system. One type derives two 6-kc audio channels that are externally demultiplexed to obtain four 3-kc channels. The second type uses four intermediate frequency chan-

nels with sideband selection and demultiplexing as an inherent part of the receiver.

4.6.2.10 Block O

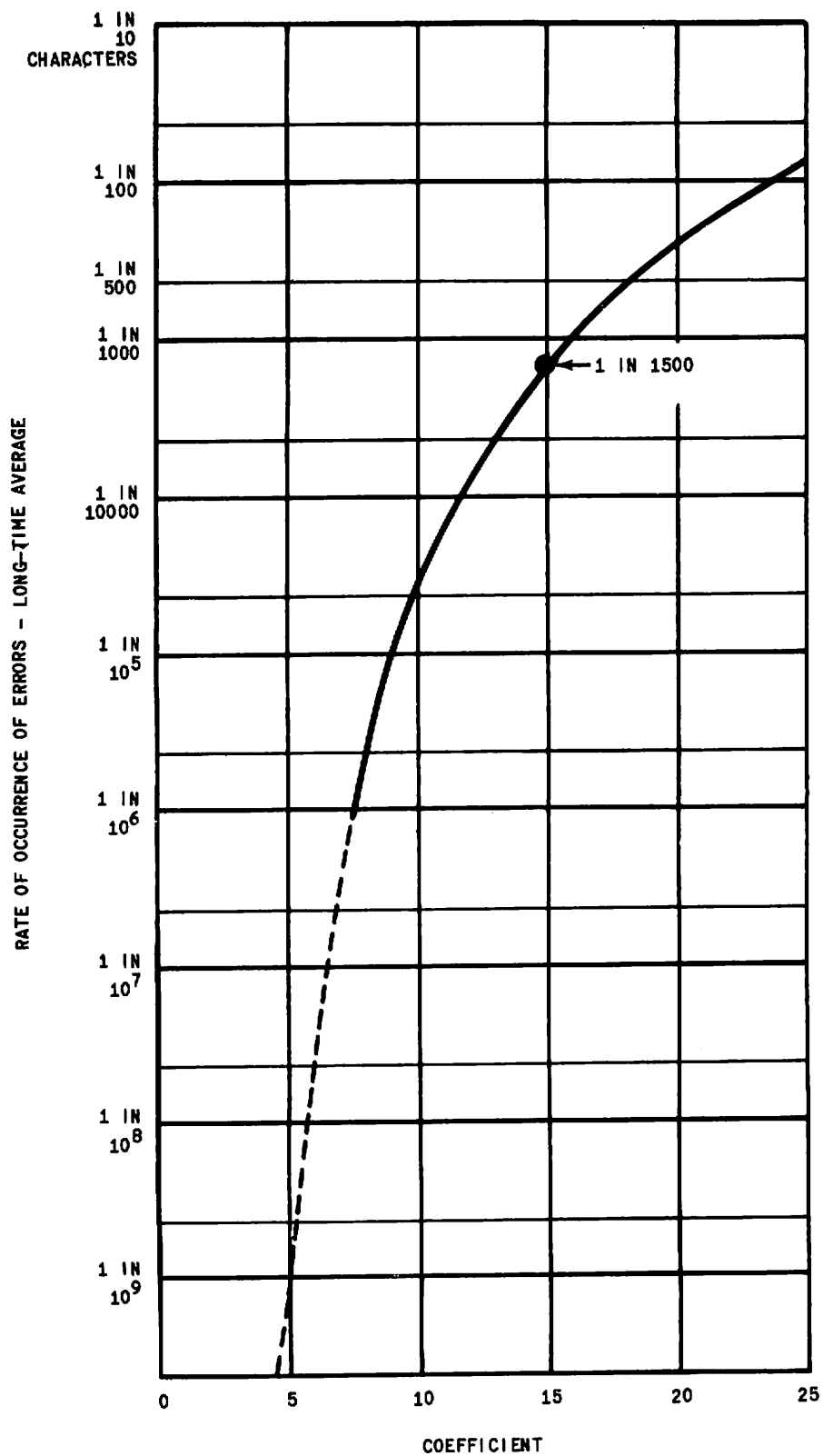
Block O covers antenna systems. These include antennas, dissipation lines, transmission lines, matching devices, antenna switching matrices, and broadband antenna multicouplers.

In the fixed point-to-point HF communications system, antennas are necessarily directional in design. Two of the most applicable types of antennas are rhombics and log periodics, the former being the more widely used. In this application, usually two rhombics are required for each point-to-point transmit circuit. Coverage of from 4 to 26 mc requires two antennas because the wideband properties of a rhombic are limited to frequencies within a ratio of 2.25 to 1. In comparison, the wider bandwidth of the log periodic antenna permits the use of only one antenna for the 4- to 26-mc bandwidth. Their disadvantages are the relatively low gain of their broad angle patterns and the complex structure of the most practicable types. The log periodic antenna requires a smaller area than the rhombic, but is more expensive and usually requires a ground screen.

4.7 Telegraph Transmission Coefficients

4.7.1 Description. In contrast with telephone and facsimile communications, transmission impairment of teletype has no noticeable effect on the flow of traffic, until it reaches the point where actual errors appear in received messages.

Based on statistical data of signal distortions, ratings known as telegraph transmission coefficients are assigned to various parts of complex telegraph circuits. These coefficients are used to determine whether or not any layout will be satisfactory with regard to error occurrence rate. In this rating system, each part of a circuit is assigned a numerical coefficient in accordance with the transmission impairment it produces. The coefficients for the parts of a proposed layout are then added to obtain the overall coefficient, which indicates whether or not the circuit will operate satisfactorily. Figure B-19 shows the theoretical relation between the coefficient value and the average error occurrence rate due to circuit transmission effects. For coefficients of less than 6 or 7, the usual values for a high grade circuit of one or two sections, such errors are rare. On the other hand, for high coefficients (15 and up) an error may be expected once in a few hundred characters. In the American commercial teletypewriter service the coefficient limit is 10, or one error in 44,000 characters. Thus, the smaller the coefficient the larger the number of characters that can be received with only one error.



RATE OF ERRORS VERSUS TELEGRAPH COEFFICIENT OF CIRCUIT
FIGURE B-19

4.7.2 Application of Telegraph Transmission Coefficients. In using telegraph coefficients, a diagram is drawn for a tentative telegraph network layout, and a coefficient is selected from the appropriate table for each part of each telegraph circuit. Then a computation is made of the overall coefficient from each station to every other station, and no regeneration is assumed. If any overall figure exceeds the desired limit of 15, it will then be necessary either to substitute better transmission sections, or to divide the circuit into parts by inserting one or more regenerative repeaters. There is no particular rule, comparable to those covering losses in a telephone system, which define how the permissible overall telegraph transmission coefficient should be divided between trunks, repeater section, and loops or extension circuits. However, the circuit configuration should be arranged to place the repeater at a point that would, as near as possible, equally divide the total coefficient. Given a total coefficient of 15, the repeater would be situated to provide a coefficient of 7.5 preceding and following it.

4.7.3 Long-Distance Telegraph Transmission Coefficients. Coefficient data is available for various types of telegraph line sections. Table B-1 presents representative coefficients for wire line sections used for start-stop teletypewriter operation. A carrier telegraph section consists of a telegraph channel terminal, a representative line to a distant point (19-gage lead-covered cable, average section of 100 miles for polar operation), and a distant telegraph channel terminal. Similarly, a single DC telegraph section consists of a repeater, a line to a distant point, and a repeater at that point. When two DC sections are operated directly in tandem, the intermediate point equipment may be either one intermediate repeater or two terminal repeaters connected back-to-back. The overall coefficient of a multisection

circuit is the sum of the coefficients of the several sections in tandem, plus those of the loops.

4.7.4 Local Area Telegraph Transmission Coefficients. Coefficients for local loops are listed in Table B-2. These values are intended to cover the normal range of conditions met in practice. The minimum figure should be used for very short distances, usually in loop circuits that do not extend out of a building. The maximum values apply to loops near the maximum length (up to 25 miles) under unfavorable conditions with regard to construction, maintenance, and interference. Any radio loops used should have the coefficients corresponding to a good wire loop.

4.7.5 Use of Regenerative Repeaters to Reduce Coefficients. When a regenerative repeater is inserted in a start-stop teletypewriter circuit at an intermediate point, the repeater may be considered as dividing the circuit into two separate parts, since such a repeater reforms and retimes the signals. The overall coefficient for each of these parts may then be computed separately, and the greater of the two coefficients used as the overall coefficient for the entire circuit. Figure B-20 illustrates the application of a regenerative repeater to a fixed teletypewriter wire circuit. When the coefficients of all the parts of the circuit are added, the overall coefficient of the circuit (without the regenerative repeater) would have exceeded a value of 18. A regenerative repeater at C divides the circuit into two parts, and the coefficients of the two sections are 7 and 11. The larger of these values (11) is the coefficient of the entire circuit when the regenerative repeater is inserted at C. This is an acceptable value. Theoretically, it would be better to place the repeater at terminal D, thus dividing the total coefficient (18) into two nearly equal parts. Practical considerations such as space, power, and logistics resulted in station C being selected

TABLE B-1
TELEGRAPH TRANSMISSION COEFFICIENTS, WIRE LINE SECTIONS

TYPE OF EQUIPMENT	COEFFICIENT		
	60 or 66 WPM	75 WPM	100 WPM
Telegraph Terminal AN/TCC-4, each section	2-4	3-6	4-8
Telegraph Terminal AN/FCC-3, each section	2-4	3-6	4-8
Telegraph Terminal TH-5/TG, each section	2.5-5	4-8	5-10
Telegraph Repeater TG-30, one DC section	5-7		
Telegraph Repeater TG-30, two DC sections	9-12		

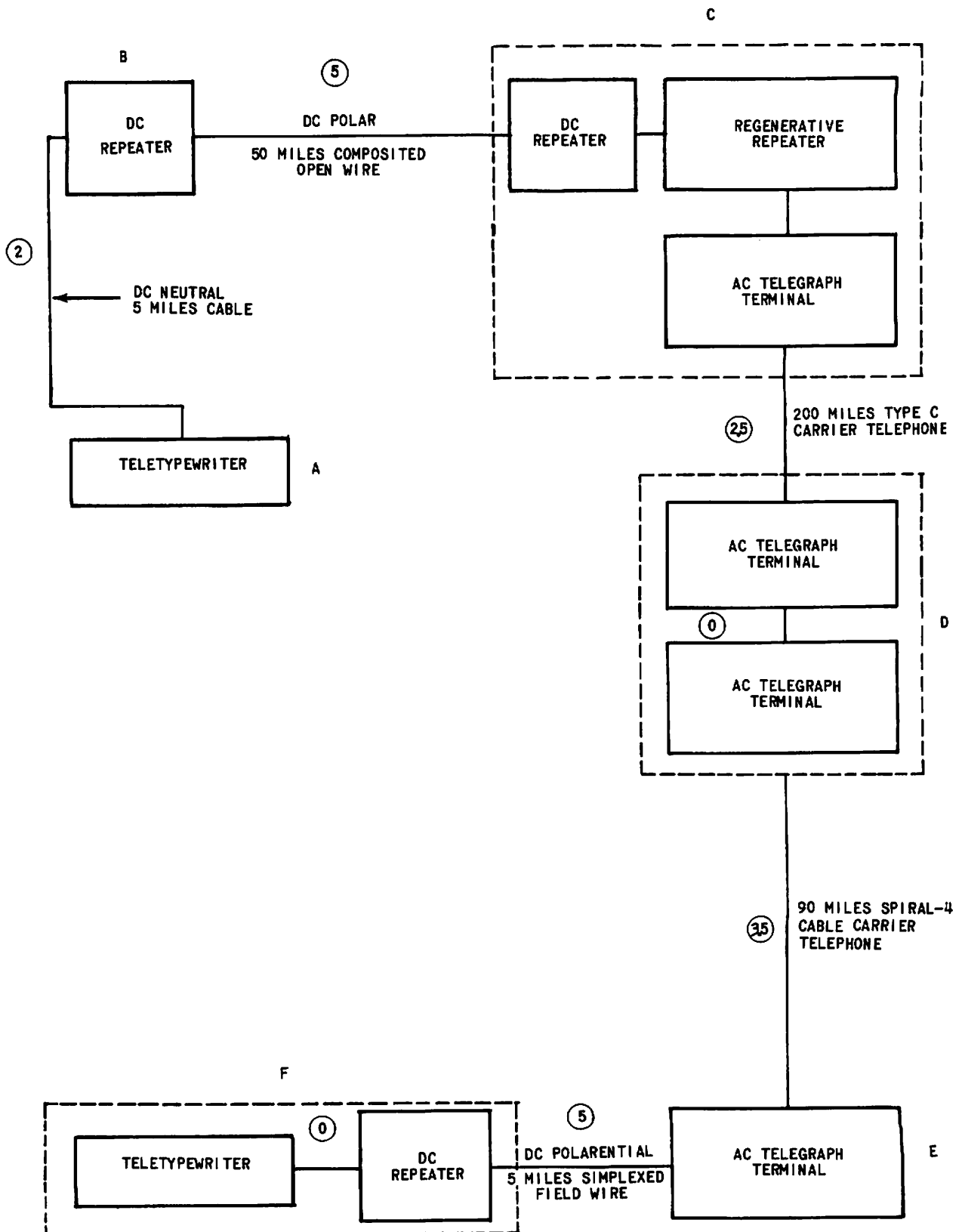
NOTE: Maximum and minimum coefficient values are provided to cover a wide range of conditions.

as the alternate location of the repeater. If a regenerative repeater cannot be installed at a suitable point, the layout must be revised. In some cases high-grade long

sections are provided between some of the more widely separated points, and the intermediate stations thus removed are connected back to the nearest terminal.

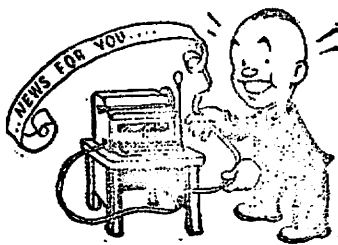
TABLE B-2
TELEGRAPH TRANSMISSION COEFFICIENTS, LOCAL AREA LOOPS

OPERATION CONDITION	COEFFICIENT		
	60 and 66 WPM	75 WPM	100 WPM
Neutral to a teletypewriter or to a DC line unit from a DC telegraph repeater.	0-2	0-3	0-4
Neutral to a teletypewriter or a DC line unit from a VF carrier terminal.	0-5	0-7	0-10
Polar or polarential to line side of distant DC telegraph repeater.	5-7	8-11	
Switchboard BD-100 line.	2-7	3-10	
AC loop between telegraph carrier terminals.	0-4	0-7	0-9

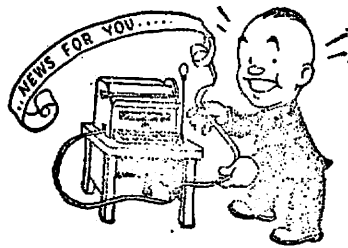


NOTE: CIRCLED NUMBERS ARE COEFFICIENTS.

USE OF REGENERATIVE REPEATER TO REDUCE COEFFICIENT
FIGURE B-20



PART C
TELEGRAPH CODES



Part C

Telegraph Codes

1.0 USE OF CODES

In reviewing the various telegraphy systems used from earliest times, there is one feature common to all of them, i.e., the use of a signaling code. In most cases, a code enables substantial economies to be effected in the cost-per-channel of telegraph channels, as compared with telephone channels. The signaling code used in a particular case must be predetermined, so that a distinctive code is transmitted for each character, which can be recognized and interpreted by the person or instrument receiving it. The particular form and choice of the signaling code employed depends upon a number of factors discussed below.

First, it is necessary to know the nature of the intelligence to be transmitted; e.g., whether the code is required to transmit the letters of the alphabet and numerals only, or a great variety of character forms such as a line drawing, or the detail of a halftone photograph (as in the case of a phototelegraph system). This information determines how many different combinations of signal elements are required in order to provide a distinctive combination of signals for each of the characters or forms transmitted. The second consideration is the economic use of the code. In general, the most economic code to employ is one that provides just the exact number of combinations required for the number of characters necessary for the transmission of information. The closer this ideal is approached, the greater will be the rate at which intelligence may be transmitted, and hence greater economy in the use of circuit time. It is also evident that the selection of a code in this manner will ensure that the code is as simple as possible.

In some cases, e.g., long-distance radio circuits, telegraph signals are subject to excessive distortion and falsification due to the effects of fading, noise, atmospheric, and interference. These effects may cause one or more elements of the code signals of a character to be received incorrectly, i.e., a mark signal may be transposed into a space signal. In code systems where the number of combinations is just equal to the number of characters to be transmitted, any incorrectly received code element for a character transposes the code to

another character. This may produce an undetectable error, unless special checking means are employed by the operating staff. To reduce the vulnerability of a code to this type of error, it is necessary to employ one of the following methods:

(a) Use combinations for the various characters, which are markedly different one from another, so that minor errors in transmission of the elements of one character are less likely to transpose the code into one corresponding to another character. This method greatly increases the number of possible combinations beyond the number actually required for the range of characters to be transmitted. This excess of information is termed redundancy. Any transposition occurring during the transmission of the code will not change the combination into that of another character, but will produce a slightly mutilated received record, which can still be identified as the character transmitted.

(b) Incorporate a common characteristic in each code combination for every character so that, if this characteristic is absent when the signal is received, a special error-detecting feature of the receiving equipment operates and indicates that an error has occurred.

Facsimile and phototelegraph systems are inherently good from the point of view of error detection, as they produce a facsimile copy of the original. Minor mutilations of the signal elements during transmission only cause minor blemishes in the received copy, without being subject to erroneous interpretation at the receiving end.

Another consideration affecting the choice of the code is the method of transmission; i.e., by hand signaling (Morse key) or by means of automatic instruments (teletypewriter). In the former, it was important that the arrangement of the code should be such that the manual signal operations involved were simple and caused minimum fatigue to the operator. This implies that those characters that had the greatest frequency of occurrence should be the ones involving the least number of manual operations. The number of manual operations in the transmission of characters with a lower frequency of occurrence is less important. The frequency

of occurrence of characters depends upon the nature of the messages transmitted and varies in different languages. Marked differences exist, but letters such as e, i, and t occur with greater frequency than the letters q and z. Therefore, close attention should be paid to this factor in determining the best allocation of the code combinations in manually operated systems.

In automatic systems, the frequency of occurrence is not as important; however, there is evidence that, in the case of the 5-unit code, the inventor Murray allocated the elements of the code so that those characters having the greatest frequency of occurrence involved the least number of mechanical operations by the automatic instruments, thereby reducing mechanical wear to a minimum.

In current usage of teletypewriter message transmission, military communications have established as standard a 5-digit teletypewriter coded character set. In the past decade, an automatic electronic information processing industry has been developed, which hardly existed prior to that period. The 5-level teletypewriter coded character set has been little used as an input or output in automatic information processing. Several coded character sets designed to transmit data between automatic information processing centers have been developed. These will be discussed in detail in the following sections.

It should be noted that these teletypewriter codes as such appear only in clear text at the end instrument sets. Long-haul traffic employing multichannel carrier operation consists of bit streams outward from the terminal area.

With these general considerations in mind, a detailed examination will be made of the various telegraph codes in modern systems.

2.0 THE MORSE CODE

In manual telegraphy, the most widely used code is the Morse code. In this code, two distinctive signal elements are employed, the dot and the dash. The difference between a dot and a dash is usually one of time duration, a dash being three times as long in duration as a dot. Each character is made up of a number of dots and/or dashes. The dot and dash elements constituting any character are separated from each other by a time interval equal to the duration of one dot. The time interval between the characters for each word is equal to the duration of three dots, and the interval between words is equal to seven dots.*

*The space between words in Morse code used to be five dots, but by international agreement it was decided in 1949 to make the space between words equal to seven dots.

Thus summarizing:

- (a) A dash is equal to three dots.
- (b) The space between the signals forming a letter is equal to one dot.
- (c) The space between the letters of a word is equal to three dots.
- (d) The space between words is equal to seven dots.

To facilitate international operation, an International Morse Code has been agreed upon, and this is the code most commonly employed in Morse systems. The International Morse Code is illustrated in Figure C-1. From this figure, it can be seen that the code provides for the letters of the alphabet, figures, punctuation, and other signs.

3.0 FIVE-UNIT CODE

In teletypewriter operation, the code group for each character is of uniform length. Since the Morse code is an uneven length code, it cannot be used in teletypewriter operation, without additional code converters.

The 5-unit code has been the most commonly used code in modern printing telegraphy, and is universally employed for teletypewriter operation. The mechanical sending device in the teletypewriter divides the sending time for each character into five short code elements of equal duration. The 5-unit code is an example of what is called an even length or constant length code; i.e., one in which the number of signal elements for a character is the same for every character, and the duration of each element is constant. In the 5-unit code, each character consists of a combination of 5-signal elements, and each element may consist of either of two basic signaling conditions (marking or spacing). Thus, a total of 2^5 or 32 combinations of the signal elements is possible with this arrangement.

The 32 possible combinations available from the 5-unit code are insufficient to handle the alphabet and numbers, since 26 combinations are required for the letters of the English alphabet alone. This leaves only six combinations for numerals, symbols, or nonprinting functions. This is obviously inadequate. It was therefore necessary to adopt a plan to enable a larger number of characters to be included, and this was done as follows. Two of the 32 combinations are employed as shift-signals, which permit the remaining code combinations are employed as letters, and in the second case, the combinations are used for numerals, punctuation signs, etc. The shift-signals are often referred to as case-shift signals; i.e., one case is a letter-shift, and the other a figure-shift. When a letter-shift is transmitted, it sets the receiving instrument in a condition to recognize any signal combination subsequently received to be recorded

LETTERS				FIGURES			
a	● —	i	● ●	r	● — ●	1	● — — — — 6
b	— ● ● ●	j	● — — —	s	● ● ●	2	● ● — — — 7
c	— ● — ●	k	— ● —	t	—	3	● ● ● — — 8
d	— ● ●	l	● — ● ●	u	● ● —	4	● ● ● ● — 9
e	●	m	— —	v	● ● ● —	5	● ● ● ● ● 0
e	● ● — ● ●	n	— ●	w	● — — —	A NUMBER WHICH INCLUDES A FRACTION SHALL BE TRANSMITTED WITH THE FRACTION LINKED TO THE WHOLE NUMBER BY A SINGLE HYPHEN. FOR EXAMPLE: 1-3/4 and not 13/4 3/4-8 and not 3/48 363-1/2 4 5642 and not 3631/2 4 5642	
f	● ● — ●	o	— — —	x	— ● ● —		
g	— — ●	p	● — — ●	y	— ● — —		
h	● ● ● ●	q	— — — ● —	z	— — ● ●		

PUNCTUATION AND OTHER SIGNS

FULL STOP (PERIOD)	(.)	• — • — • —
COMMA	(,)	— — • — —
COLON	(:)	— — — • •
QUESTION MARK (NOTE OF INTERROGA- TION) OR REQUEST FOR REPETITION OF A TRANSMISSION NOT UNDERSTOOD	(?)	• • — — • •
APOSTROPHE	(')	• — — — —
HYPHEN OR DASH	(-)	— • • • • —
FRACTION BAR	(/)	— • • — •
BRACKETS (PARENTHESES) (BEFORE AND AFTER THE WORDS)	()	— • — — • —
INVERTED COMMAS (QUOTATION MARKS) (BEFORE AND AFTER WORDS)	" "	• — • • — •
ADMINISTRATIONS AND RECOGNIZED PRI- VATE OPERATING AGENCIES USING CODE CONVERTERS MAY USE THE AP- OSTROPHE TWICE, BEFORE AND AFTER THE WORDS, TO SIGNAL INVERTED COMMAS (QUOTATION MARKS).		
DOUBLE HYPHEN	(=)	— • • —
UNDERSTOOD		• • • — •
ERROR		• • • • • • •
CROSS OR SIGNAL FOR THE END OF A TELEGRAM OR OF TRANSMISSION		• — • — •
INVITATION TO TRANSMIT		— • —
WAIT		• — • • •
END OF WORK		• • • — • —
STARTING SIGNAL (TO PRECEDE EVERY TRANSMISSION)		— • — • —

THE INTERNATIONAL MORSE CODE
FIGURE C-1

in the letter case, until a figure-shift is received. Then the receiving instrument sets itself in a condition to record any subsequent signal combinations received in the figure case. That is, the interpretation of a signal combination is determined by the previous shift-signal. The use of this plan enables 30 of the available 32 combinations to have two meanings.

Codes and alphabets for 3-row teletypewriters in use today are all derived from the basic Murray 5-unit code. They agree in the assignment of codes to the 26 letters of the alphabet, the ten numerals, and the nonprinting functions (space, carriage return, line feed, figures, and letters). They differ in respect to the symbols and nonprinting functions assigned to some of the combinations in the figures-shift.

The three alphabets of interest are:

- (a) The CCITT International Telegraph Alphabet No. 2
- (b) The U.S. Military Communication Alphabet
- (c) The Weather Alphabet

These are shown in Figure C-2 as a combined table. The American Military Communication keyboard and Weather keyboard are shown in Figures C-3 and C-4, respectively.

The CCITT International Telegraph Alphabet No. 2 is the same in all respects as the American Communication version, except as follows:

<i>Upper Case</i>	<i>Usage</i>
D	WRU (who are you?), when received, causes a machine so equipped to transmit the station call sign or identification by an automatic mechanism.
F, G, H	Unassigned internationally, may be used with local meanings in national systems.
J	Audible signal (bell).
S	Apostrophe (').
V	Equality sign (=).
Z	Plus sign (+).

The 5-unit code offers a high degree of efficiency in transmission, but with the penalty that any error introduced in a bit pattern during transmission changes the pattern into an incorrect but equally valid one. There is no way of correcting or detecting the error, except by reference to the message context. Fortunately, in the case of messages of a narrative nature, the inherent redundancy in written language is often sufficient to permit errors in transmission to be both detected and corrected by inspection of the decoded text.

On the other hand, the 5-unit code is unacceptable in the modern world of figures (statistics, digital data, etc.), where the context of a character offers no clue to its accuracy, and when the transmission media (radio)

involved is subject to high error rates. In these circumstances, and also where additional characters in the alphabet are desired, a code with more signal elements per character, offering more permutations than the desired alphabet requires, must be used.

At the present time, U.S. military 5-unit teletypewriter coded character set has been established as an interim standard. The American Standard Code for Information Interchange (ASCII) (see paragraph 6.0), has been adopted as the standard code for teleprinter equipment, the same as for digital data communication equipment. This 8-unit code shall be used wherever practicable.

4.0 SIX-UNIT CODE

The characteristics of the 6-unit code are similar to those of the 5-unit code, except that the combination of signals for each character consists of six elements of equal duration for a total of 2^6 or 64 combinations. Thus, it is possible to fulfill all the functions performed by the 5-unit code without the case-shift signals. This offers advantages for traffic involving a mixture of letters and figures, since the elimination of the operations involved in the insertion of shift-signals saves time in the transmission of messages. An example of this type of traffic is stock exchange messages, which employ 6-unit teletypewriters.

The possibility of adopting a 6-unit code has been discussed at several CCITT conferences, but so far no agreement has been reached for adopting a 6-unit code for international services. The 6-unit code is presently restricted to teletypesetter applications in commercial use. It is doubtful that this code will have other applications in either military or commercial use.

5.0 DOD STANDARD MILITARY CODE FIELDATA (1960)

For a number of reasons, the 5-level teletypewriter code character set has been of little use as an input or output in automatic information processing. One reason is the requirements for a case-shift to represent the characters in the set; another is the lack of order in code assignments from the standpoint of information processing by machines.

Recognizing that a standard coded character set was required to transmit data between the various automatic information processing centers and their associated equipments, the Department of the Army developed an 8-level data transmission code (FIELDATA), which was approved as a Military Standard in 1960. (See Figure C-5.) This 8-unit code provides 2^8 or 256 different bit patterns. The code employs a single bit redundancy

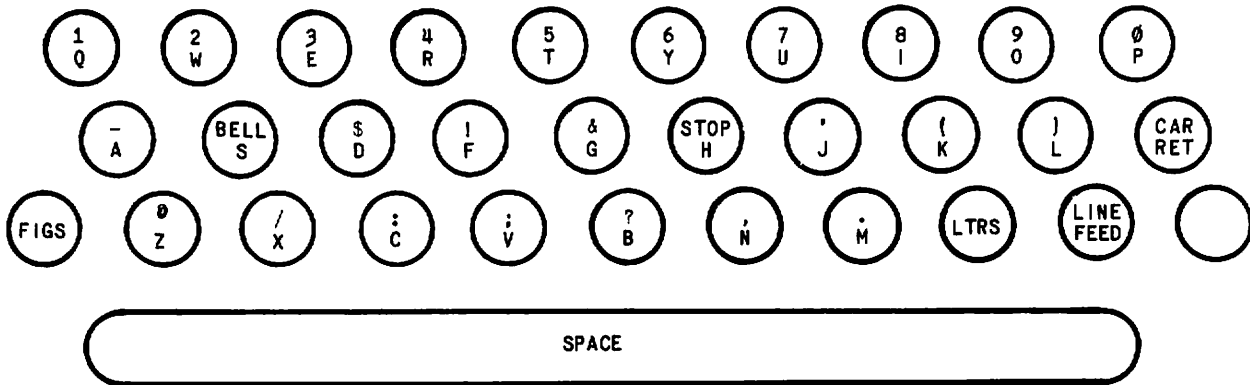
CHARACTERS				CODE ELEMENTS						
LETTERS CASE	FIGURES CASE			S T A R T	1	2	3	4	5	S T O P
	COMMUN- ICATIONS	WEATHER	*CCITT#2							
A	—	↑								
B	?	⊕								
C	:	○								
D	\$	↗	WRU							
E	3	3								
F	1	→	UNASSIGNED							
G	&	↘	UNASSIGNED							
H	STOP**	↓	UNASSIGNED							
I	8	8								
J	*	↙	AUDIBLE SIGNAL							
K	(	←								
L	)	↖								
M	.	.								
N	,	⊙								
O	9	9								
P	⊖	⊖								
Q	1	1								
R	4	4								
S	BELL	BELL	!							
T	5	5								
U	7	7								
V	;	⊙	=							
W	2	2								
X	/	/								
Y	6	6								
Z	"	+	+							
BLANK										
SPACE										
CAR. RET.										
LINE FEED										
FIGURE										
LETTERS										

*THIS COLUMN SHOWS ONLY THOSE CHARACTERS WHICH DIFFER FROM THE AMERICAN COMMUNICATION VERSION.

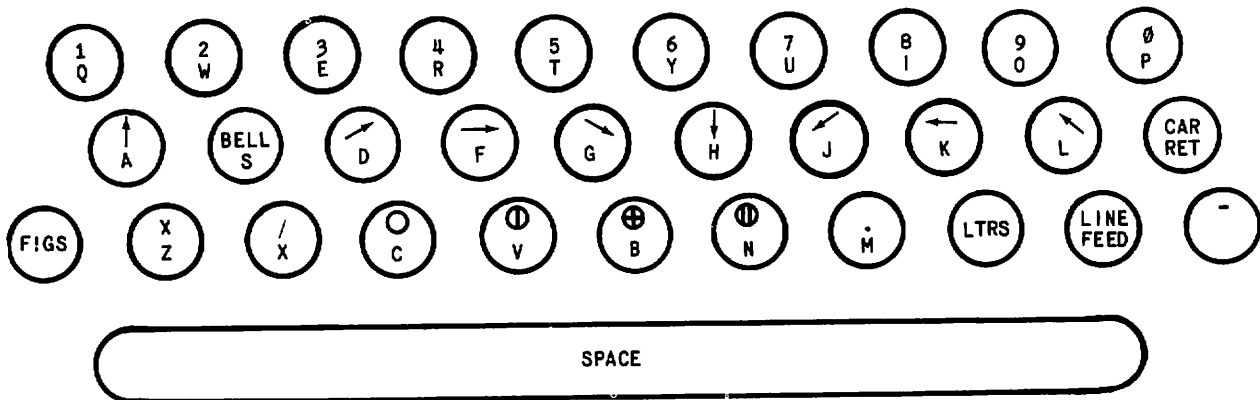
**FIGURES CASE H (COMM) MAY BE STOP OR #

LEGEND	
	MARKING ELEMENT
	SPACING ELEMENT

COMMUNICATIONS AND WEATHER CODES, CCITT
INTERNATIONAL TELEGRAPH ALPHABET NO. 2
FIGURE C-2



AMERICAN MILITARY COMMUNICATION KEYBOARD
FIGURE C-3



WEATHER KEYBOARD
FIGURE C-4

$I_1 - I_2 - C \rightarrow$				000	100	010	110	001	101	011	111
D_0	D_1	D_2	D_3	P	P	P	P	P	P	P	P
0	0	0	0	1	0	0	1	MAST. SP.	0	1	0
1	0	0	0	0	1	1	0	UP. CASE	1	0	1
0	1	0	0	0	1	1	0	LWR. CASE	1	0	1
1	1	0	0	1	0	0	1	LINE FEED	0	1	0
0	0	1	0	0	1	1	0	CAR. RET.	1	0	0
1	0	1	0	1	0	0	1	SPACE	0	1	0
0	1	1	0	0	0	0	1	A	0	1	0
1	1	1	0	1	1	1	0	B	1	0	1
0	0	0	1	0	1	1	0	C	1	0	1
1	0	0	1	1	0	0	1	D	0	1	0
0	1	0	1	0	0	0	1	E	0	1	0
1	1	0	1	1	1	1	0	F	1	0	1
0	0	1	1	0	0	0	1	G	0	1	0
1	0	1	1	1	1	1	0	H	1	0	1
0	1	1	1	0	1	1	1	I	1	0	0
1	1	1	1	1	0	0	1	J	0	1	0
				1	0	0	0			1	0
				CONTROL FUNCTIONS (UNDER STUDY)				ALPHANUMERICS			
										+	(STOP)
											IDLE

SEQUENCE OF SIGNAL ELEMENTS FOR SERIAL TRANSMISSION: $D_0 - D_1 - D_2 - D_3 - I_1 - I_2 - C - P$
 EXAMPLE: 0 0 0 1 0 0 1 1

P IS STANDARD TRANSMISSION PARITY BIT ADDED TO GIVE ODD PARITY FOR ERROR CONTROL.
 FOR PUNCHED TAPE, ALL PARITY BITS ARE AUTOMATICALLY REVERSED TO GIVE EVEN PARITY.

DOD STANDARD CODED CHARACTER SET FOR INFORMATION INTERCHANGE (FIELDATA)
 FIGURE C-5

check; i.e., one bit is added to each code bit pattern, so the total number of 1's will always be odd or even as arbitrarily selected. This added bit is called the parity or check bit, supplying a predictable check to each coded character. Since the parity bit has two possible values, 1 or 0, only one confers validity on a bit pattern. This parity bit occupies one bit position of the 8-unit code effectively halving the number of available bit patterns for assignment to the characters. In the case of the FIELDATA code, one-half of 256 (or 128) bit patterns are available for assignment to characters. The 128 bit patterns are further divided into two groups of 64, each distinguished by the value of a particular bit known as the control bit. The bit pattern in one group (all identified by a control bit 1) are assigned to alphanumeric characters, such as letters, numerals, punctuation signs, etc. The bit patterns in the other group (all identified by a control bit 0) are assigned to control function characters intended to be used for a variety of purposes other than the composition of the message text. These purposes include setting up connections through automatic switching centers, and other control and supervisory signals.

The components of a standard form 8-unit FIELDATA code are:

DETAIL BITS— D_0 , D_1 , D_2 , and D_3
INDICATOR BITS— I_1 and I_2
CONTROL BIT—C
PARITY BIT (odd)—P

The sequence of transmission in serial bit operation is as shown in Figure C-5, with D_0 first and P last.

The FIELDATA code is used in a number of implemented military projects.

6.0 AMERICAN STANDARD CODE FOR INFORMATION INTERCHANGE (ASCII)

The growing multiplicity of codes used in computer and other data processing systems led to a study of the problem by the American Standards Association, with the object of devising a new coded character set that would be acceptable for the interchange of information among information processing systems, communication systems, and associated equipment. There was no attempt to standardize any code for internal use in computers. Existing and proposed codes were considered, including the FIELDATA. The criteria employed in finding an acceptable code were much the same as those used in developing the FIELDATA code. The form of this new code and alphabet is shown in Figure C-6. Slight variations of this format are expected, and will be shown in Appendix I of MIL-STD-188B. Figure C-7

is a suggested version of a 4-row keyboard associated with the ASCII code.

ASCII is a 7-unit code, without redundancy, and accordingly provides 128 different bit patterns, all available for assignment to characters. The bits are numbered from b_7 (high order) to b_1 (low order).

Columns 2-7 in Figure C-6 contain the English alphabet (upper and lower case letters), the numerals 0-9, and a number of punctuation signs and mathematical symbols.

Columns 0 and 1 contain those control functions that were considered most important to meet the requirements of data processing, as well as communications. To provide for enlarging and extending the code, an Escape character was included, by means of which the system can be shifted out of ASCII altogether, and an entirely different code or an amorphous bit stream used instead.

7.0 ERROR CONTROL PRACTICES

7.1 General Description

If traffic is transmitted in the simplest manner direct from a teletype or similar 5-unit apparatus, messages can be corrupted in two ways. First, if one or more of the five information elements of a character is received incorrectly, a wrong character will be printed, since all 32 possible arrangements of the five information elements are accepted by the receiving teleprinter. Second, if a start or stop element is received incorrectly, the receiving teleprinter will lose phase temporarily, and a number of characters will be printed incorrectly until phase is regained. Loss of phase can be overcome by synchronous operation which involves discarding the start-stop elements before transmission, and reinserting them correctly at the receiver, thereby reconstructing a start-stop signal to drive the teletype. For synchronous operation more complicated terminal equipment is required, because the receiver must be synchronized and phased correctly to the incoming signal; however, this method can reduce the printed error-rate by about 75 percent; even when the unprotected 5-unit teleprinter code is retained.

Further reduction in the printed error rate can be obtained by using a protected code, which permits error correction in place of the teleprinter code, for transmission over the radio path. The error-correcting terminals will generally provide automatic translation between the teletype code and the protected code, and permit integration with normal teleprinter equipment at the ends of the radio link.

The protected codes have error-detecting or error-correcting properties, or both, depending on the other

LEGEND (CONTINUED)

VT . . . VERTICAL TABULATION. A LAYOUT CHARACTER WHICH CONTROLS THE MOVEMENT OF THE PRINTING POSITION TO THE NEXT OF A SERIES OF PREDETERMINED PRINTING LINES.

FF . . . FORM FEED. A LAYOUT CHARACTER WHICH CONTROLS THE MOVEMENT OF THE PRINTING POSITION TO THE FIRST PREDETERMINED PRINTING LINE ON THE NEXT FORM.

CR . . . CARRIAGE RETURN. A LAYOUT CHARACTER WHICH CONTROLS THE MOVEMENT OF THE PRINTING POSITION TO THE FIRST PRINTING POSITION ON THE SAME PRINTING LINE.

SO . . . SHIFT OUT. THE SHIFT-OUT CHARACTER MEANS THAT ALL THE CODE COMBINATIONS WHICH FOLLOW SHALL BE INTERPRETED AS OUTSIDE OF THE CHARACTER SET OF THE STANDARD CODE TABLE UNTIL A SHIFT-IN CHARACTER IS REACHED.

SI . . . SHIFT-IN. THE SHIFT-IN CHARACTER MEANS THAT ALL THE CODE COMBINATIONS WHICH FOLLOW SHALL BE INTERPRETED ACCORDING TO THE STANDARD CODE TABLE.

DLE . . . DATA LINK ESCAPE. A TRANSMISSION CONTROL CHARACTER WHICH WILL CHANGE THE MEANING OF THE FOLLOWING CODE COMBINATION(S). IT IS USED EXCLUSIVELY TO PROVIDE SUPPLEMENTARY CONTROL IN DATA TRANSMISSION NETWORKS.

DCI-DC4 . DEVICE CONTROLS.

NAK . . . NEGATIVE ACKNOWLEDGE. A TRANSMISSION CONTROL CHARACTER TRANSMITTED BY A RECEIVER AS A NEGATIVE RESPONSE TO THE SENDER.

SYN . . . SYNCHRONOUS IDLE. A TRANSMISSION CONTROL CHARACTER USED BY A SYNCHRONOUS TRANSMISSION SYSTEM IN THE ABSENCE OF ANY OTHER CHARACTER (CONDITION TO PROVIDE A SIGNAL FROM WHICH SYNCHRONISM MAY BE ACHIEVED OR RETAINED).

ETB . . . END OF TRANSMISSION BLOCK. A TRANSMISSION CONTROL CHARACTER USED TO INDICATE THE END OF A BLOCK OF DATA FOR TRANSMISSION PURPOSES.

CAN . . . CANCEL. A CHARACTER USED TO INDICATE THAT THE DATA WITH WHICH IT IS ASSOCIATED IS IN ERROR OR IS TO BE DISREGARDED.

EM . . . END OF MEDIUM. A CONTROL CHARACTER WHICH MAY BE USED TO IDENTIFY THE PHYSICAL END OF THE MEDIUM, OR THE END OF THE USED, OR WANTED, PORTION OF INFORMATION RECORDED ON A MEDIUM. THE POSITION OF THIS CHARACTER DOES NOT NECESSARILY CORRESPOND TO THE PHYSICAL END OF THE MEDIUM.

SS . . . START OF SPECIAL SEQUENCE. A CHARACTER WHICH IS USED TO INDICATE THE START OF A VARIABLE LENGTH SEQUENCE OF CHARACTERS WHICH HAVE SPECIAL SIGNIFICANCE OR WHICH ARE TO RECEIVE SPECIAL HANDLING. THIS SS MAY BE USED FOR TRANSMISSION CONTROL PURPOSES.

ESC . . . ESCAPE. A FUNCTIONAL CHARACTER WHICH MAY BE USED FOR AN EXTENSION OF THE STANDARD CHARACTER SET OF THE CODE BY CHANGING THE MEANING OF THE NEXT SINGLE FOLLOWING CODE COMBINATION. THE PRECISE MEANING OF THIS FOLLOWING CHARACTER REQUIRES PRIOR AGREEMENT BETWEEN THE SENDER AND THE RECIPIENT OF THE DATA. THE "ESCAPE" CHARACTER ITSELF MAY THEREFORE BE REGARDED AS A WARNING OR NON-LOCKING SHIFT CHARACTER AFFECTING THE NEXT SINGLE FOLLOWING CHARACTER. THE SINGLE CHARACTER WHICH FOLLOWS "ESCAPE" MAY BE INTERPRETED AS A GRAPHIC OR CONTROL CHARACTER NOT INCLUDED IN THE STANDARD SET. ALTERNATIVELY THE MEANING OF THIS SINGLE CHARACTER MAY BE "GO INTO CODE X AND STAY IN IT."

FS . . . FILE SEPARATOR. (SEE 15 FOR DEFINITION)

GS . . . GROUP SEPARATOR. (SEE 15 FOR DEFINITION)

RS . . . RECORD SEPARATOR. (SEE 15 FOR DEFINITION)

US . . . UNIT SEPARATOR. (SEE 15 FOR DEFINITION)

IS . . . INFORMATION SEPARATOR. THERE ARE FOUR INFORMATION SEPARATORS (FS, GS, RS, US) WHICH HAVE A HIERARCHICAL RELATIONSHIP WITH EACH OTHER. THEY ARE RELATED, AS FOLLOWS:
UNIT SEPARATOR (US) RECORD SEPARATOR (RS), GROUP SEPARATOR (GS), AND FILE SEPARATOR (FS). (FS) IS THE MOST POWERFUL SEPARATOR. A "UNIT" CANNOT INCLUDE A "FILE", "GROUP", OR "RECORD."

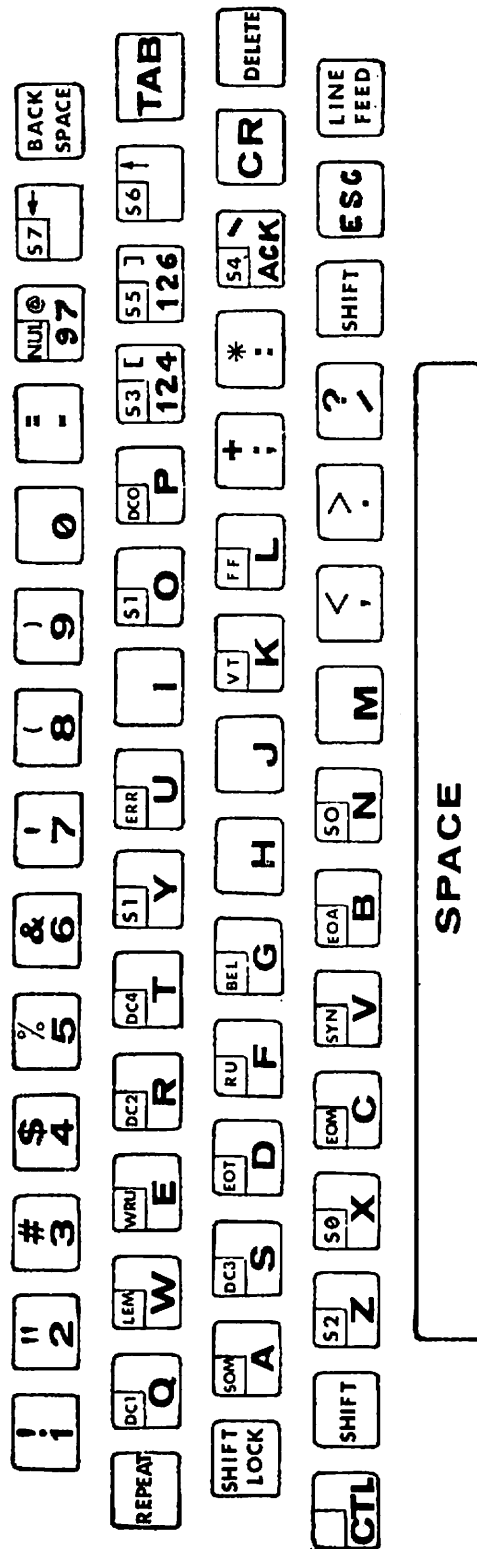
A "RECORD" MAY INCLUDE (AND IF IT INCLUDES, IT INCLUDES COMPLETELY) A VARIABLE NUMBER (NONE, ONE OR MORE) OF "UNITS."

A "RECORD" CANNOT INCLUDE "FILE" OR "GROUP."

A "GROUP" MAY INCLUDE (AND IF IT INCLUDES, IT INCLUDES COMPLETELY) A VARIABLE NUMBER (NONE, ONE OR MORE) OF "RECORDS" AND/OR "UNITS." A "GROUP" CANNOT INCLUDE A "FILE."

A "FILE" MAY INCLUDE (AND IF IT INCLUDES, IT INCLUDES COMPLETELY) A VARIABLE NUMBER (NONE, ONE, OR MORE) OF "GROUPS", "RECORDS", AND/OR "UNITS."

SP . . . SPACE. A NORMALLY NON-PRINTING GRAPHIC CHARACTER USED TO SEPARATE WORDS. IT IS ALSO A LAYOUT CHARACTER WHICH CONTROLS THE MOVEMENT OF THE PRINTING POSITION, ONE PRINTING POSITION IN THE FORWARD DIRECTION.



C-13

THIS KEYBOARD IS NOT INTENDED AS A STANDARD AND IS INCLUDED FOR INFORMATION PURPOSES ONLY

ASSUMPTION: LOWER CASE ALPHABET WILL BE ASSIGNED BY ASA TO THE UNASSIGNED PORTION OF ASCII

OPERATING LEGEND

1. SHIFT PRODUCES UPPER CHARACTER ON KEY TOP (NOT WITHIN SMALL SQUARE) OR UPPER CASE OF A LETTER.
2. UNSHIFT PRODUCES LOWER CHARACTER ON KEY TOP OR THE LOWER CASE OF A LETTER.
3. CONTROL (CTR) PRODUCES THE CHARACTER WITHIN THE SMALL SQUARE ON THE KEY TOP.

LOGIC LEGEND

KEY	LOGIC LEGEND	BITS
SHIFT	765	100(16 CHARACTERS)
	110	101(16 CHARACTERS)
	111	010(1st 12 CHARACTERS)
	011	011(LAST 4 CHARACTERS)
CONTROL	010	000(16 CHARACTERS)
	110	001(16 CHARACTERS)
	111	

NOTE: 97, 124, AND 126 ON THE @, [,] KEYS RESPECTIVELY ARE THE NUMERIC NUMBERS OF THE ASCII CHARACTERS THAT ARE STILL UNASSIGNED AFTER PLACING THE LOWER CASE ALPHABET IN THE UNASSIGNED POSITION.

FIGURE 1. Four row keyboard.

FOUR-ROW KEYBOARD
FIGURE C-7

characteristics of the system. They also possess redundancy in the sense that only some of all the possible permutations are treated as invalid. The invalid arrangements of the elements of each character, when transmitted, are not acceptable to the receiver.

For major commercial point-to-point systems, the method generally employed involves the use of an error-detecting code in which individual 5-unit teletype characters are translated to 7-unit characters, each of which contains three elements of mark polarity and four elements of a 7-unit code, 35 have this characteristic and are allocated to the 32 teleprinter characters and to three supervisory conditions. All errors affecting an odd number of elements in a character, and some errors affecting an even number of elements, can be detected at the receiver by inspection of the mark/space ratio.

7.2 Operational Error-Control Techniques

Error-control systems may be divided into two basic classes: (a) systems that detect and indicate to the recipient that a given character, word, or message contains one or more errors; and (b) systems that correct these errors by detecting the error and requesting a repetition of the message from the transmitting end of the system, or by using a code structure that permits determination of the correct characters from the received signals despite errors.

The choice of the operational error-control technique to be employed is often determined by user requirements unrelated to the code effectiveness in combating errors occurring during transmission. Such performance criteria as permissible overall delay, synchronous transmission, and format restrictions will strongly influence the error-control system design.

7.3 Error Detection and Automatic Repeat Request (ARQ)

In this mode of operation, information is most conveniently encoded into blocks containing redundant bits. Upon detection of an error at the receive terminal decoder, a request for repeat is sent to the transmit terminal via a return channel. If a wait for acknowledge operation is used, the next information block is not sent until an acknowledgment is received at the transmit terminal. In this case, only one block of information need be repeated. A more efficient mode of operation is for continuous data to be sent from the transmit terminal. In this instance, upon receipt of a repeat request, a minimum of two data blocks must be repeated, since the sending of a second block will have been initiated prior to the receipt of the repeat request at the transmitter.

With either ARQ mode, the data are subjected to interruptions when repeat requests occur. As a result, synchronism cannot be maintained between points A and B without the use of additional buffering. If buffers are used to attempt to provide an even flow of data, the rate of transmission must exceed the incoming data rate to permit the emptying of the receive buffer. This requires data conversion equipment.

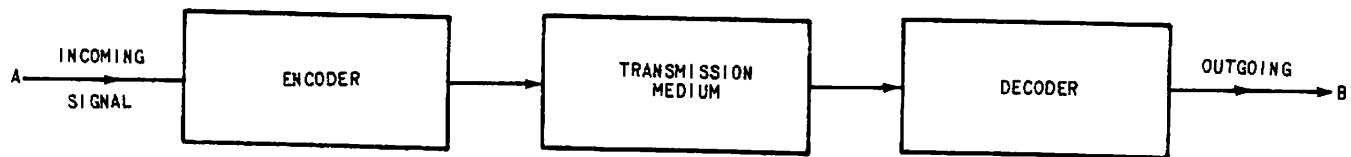
7.4 Forward Error-Correcting Codes

Forward error-correcting codes introduce redundancy with the transmitted message stream, and the information contained in these redundant bits is used to detect and correct errors in the message at the receiving end. The code redundancy required for error correction is considerably higher than that for error detection for a given protection against errors. The system employing this technique of error control is shown in Figure C-8.

In the previous paragraph, it was noted that the ARQ method of error detection and correction can only be operated on a point-to-point circuit when a return channel is available. In the event a return channel is not available for broadcast systems or point-to-point circuits, forward error-correcting codes employing greater redundancy can be used. Thus errors can be corrected without reference back to the transmitting terminal.

Basic rules for error-detecting and correcting codes indicate that where the unprotected code has five elements, the minimum number of elements in the characters of a code permitting single element errors to be detected is six, and the minimum number of elements permitting single element errors to be corrected is nine. At least ten elements are required in each character to permit correction of single element errors, and detection of errors affecting two elements. In the latter case, the characters of the new code have twice as many elements as the number of information elements in the characters of the original code. As the number of elements in a code increase, the probability of error on a character basis also increases, since there are more elements in each character to go wrong. Objections to greater number of elements than ten per character are the loss of traffic carrying capacity, or the need for higher signaling speeds.

A representative example of the forward error-correcting code technique is the Marconi-Autospec, single-path, error-correcting telegraph equipment. Two terminal units are required, the transmit unit (encoder) associated with the transmit teleprinter, and the receive unit (decoder) located at the receive teleprinter. A 10-unit code is employed, made up of five information elements and five parity elements. The transmit equipment accepts standard teletypewriter code signals from



SYSTEM EMPLOYING FORWARD ERROR CORRECTION
FIGURE C-8

a keyboard teleprinter or automatic tape sender. The receiver output is in standard teletypewriter code for operation of a page printer, reperforator, or tape printer. In the transmit terminal, the start-stop elements of the teletypewriter code are not transmitted and five parity elements are added to the five information elements. The transmit and receive Autospec terminals are maintained in synchronism and the start-stop, machine-synchronizing pulses are regenerated and added to the outgoing signal at the Autospec receiver.

Use of the above single-path, error-correcting terminals can provide a means of reducing the error rates of high frequency radio telegraph circuits, which do not operate with a protected code system. The performance of radio teleprinter circuits is often degraded by superimposed noise and distortion caused by fading and interference. The error correcting equipment will detect and correct single errors in the received characters, while the majority of multiple mutilations of the information elements in a character will cause an error symbol to be printed in the copy.

Forward error-correcting codes are unidirectional, i.e., they do not require the use of a return channel. This feature makes them especially attractive for communication situations where a return path is impractical, such as transmission to a military unit or ship under radio silence.

7.5 Hybrid Techniques

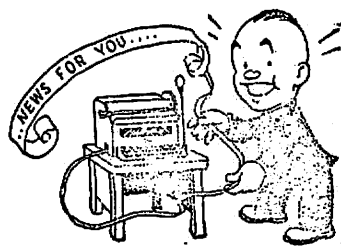
One hybrid technique combines both forward error correction and ARQ within a single code structure. This mode of operation may take either of two forms:

(a) Forward error correction is the basic technique, and repeat requests are initiated only under decoder failure. This mode can use convolutional code structures, which are designed to correct errors under most anticipated channel conditions, with repeat requests occurring only when the decoder is unable to correct conditions.

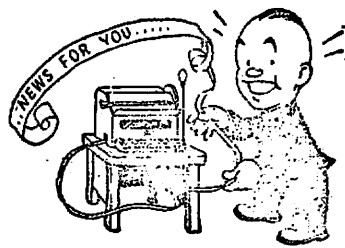
(b) In the second system, a modest amount of forward error correction is incorporated into a block structure used in a basically ARQ system to somewhat reduce the number of repeat requests and thereby increase channel efficiency.

Another hybrid technique uses forward error correction (FEC) in tandem with ARQ, and separate encoders and decoders are used for each function. The use of FEC preserves the characteristics of a physical connection between ARQ transmit and receive terminals, and causes no difficulty in operation.

Hybrid techniques generally exhibit system characteristics similar to those of the simple ARQ system described previously. The effect of including forward error correction will lessen the probability of a repeat request. The technique of FEC in tandem with ARQ could be representative of the case where a common user facility employs FEC in order to upgrade a basic service, and the user provides an ARQ system to achieve error rates somewhat better than those guaranteed by the common user facility.



PART D
METHODS OF TELETYPEWRITER OPERATION



Part D

Methods of Teletypewriter Operation

1.0 TIMING OF SIGNALS

Where signals are generated by one teletypewriter and received by another machine, the timing of the receiving machine must be the same or very close to the timing of the transmitting machine. The teletypewriter is a motor-driven device, and synchronism between machines is dependent upon the constant speed similarity of the motors used in both machines. Where standard AC power is available, synchronous-type motors are satisfactory. In the early days of telegraphy, synchronous power was not available for driving teletypewriters, and speed-error occurrences between transmitting and receiving machines were a major concern. Speed-governed motors must still be used where AC power is neither available nor reliable; however, their use is avoided whenever possible because of maintenance problems involved.

The start-stop method of teletypewriter operation reduced the problem of poor synchronism by starting and stopping the receiving printer for each character, and with this purpose in mind the transmitting machine was arranged to send special start and stop signals.

The principle of start-stop operation is now universally used on modern teletypewriter machines.

2.0 START-STOP OPERATION

2.1 Synchronization

In the start-stop method of operation, synchronization of transmitter and receiver is established anew for each character, because there is no specified relationship between the timing of successive characters. Between characters, transmitting and receiving distributors are held in a rest position, and a continuous marking signal is transmitted. To send a character, the transmitting distributor starts and sends a start-spacing signal of 1-unit interval duration, followed by the five (or more) information elements of the code. After the last information element, the signal reverts to, or remains in, the marking condition, or stop signal. The minimum duration of the stop signal is fixed by the design of the

transmitter. The use of a stop element longer than one code element increases the tolerable difference between the duration of the code elements generated by the transmitter and the strobing intervals at the receiver. Teletypewriters generating stop elements of the minimum duration of 1.42-unit intervals are common in the United States.

In a free-running tape reader, or in a keyboard machine being manipulated at its exact rated speed by the operator, the start element of the next character will begin as soon as possible; i.e., after the minimum stop element duration. According to military standards for 5-unit codes, this is a 1.0-unit interval. However, in what is called stepped operation, the transmitting machine will not start to transmit a character until a control or stepping signal is received from an external source. Stepped operation is necessary when start-stop equipment is to transmit signals into a synchronous system such as a time-division-multiplex, modulation-rate converter, or some types of single-channel security devices. The stepping pulses are timed so the start-stop transmitter generates each character at the exact time required for access to specific channels of the multiplex system. Thus, the transmitter neither outruns nor falls behind the synchronous system, and character count integrity is maintained. Character Count Integrity is that condition in which the precise number of characters that are originated in the message text, or per unit time, are preserved.

In nonstepped keyboard operation, there is no upper limit to the duration of the stop element, since it depends entirely on how soon the operator presses the key for the following character.

2.2 Character Interval

Character Interval is a term used in discussing the duration of a transmitted character. Its general definition is:

The total number of unit intervals (including synchronizing, intelligence, error checking, or control bits) required to transmit any given character in any

given communication system. Extra bits that are not associated with individual characters are not included.

The meanings of certain terms used in the above definition are as follows:

Bit is a contraction of *BINARY DIGIT*.

Synchronizing bits are, for example, the start and stop pulses used in start-stop operation.

Intelligence bits are those that form the basic permutation code (e.g., in a 5-unit code there are five intelligence bits).

Error checking bits are character parity bits when introduced as a part of each character.

Control bits are used in the FIELDATA code to indicate whether a character is in the alphanumeric or the control function group.

Extra bits that are not associated with individual characters include error checking bits which are used for checking of blocks of characters, etc.

The transmitting character interval of a start-stop character includes the start element, the information elements, indicator, control and character parity elements (if any), and the minimum stop element. The character is measured in unit intervals; e.g., a character consisting of 1-unit interval start signal, 5-unit interval information elements, and a 1.42-unit interval stop signal has a character interval of 7.42-unit intervals.

The receiving distributor starts at the beginning of the start element, and, if synchronism is perfect, it will pass through the positions that correspond precisely with the successive signal elements as they are received. The drive motor of the receiving machine at times may run slightly slower than the motor at the transmitter. To allow for this, the printer is required to reach its rest position within 60 percent of a unit interval before the end of the minimum-duration stop signal.

The interval between the moment that the receiver starts in response to a start signal and when it stops in its rest position is called the receiving character interval.

3.0 SYNCHRONOUS SYSTEMS

3.1 General Information

Synchronous systems are signaling systems which do not have start spaces, or stop marks, but consist of a continuous stream of binary elements.

By the use of very accurate timing devices, the transmitting and receiving machines are kept in a correct timing relationship. Because of lack of timing errors, distortion is not so prevalent and higher operation speeds are obtainable than with start-stop operation.

The end instruments are usually start-stop teletype-writers, and code converters are required to change the start-stop signals to codes used in synchronous systems. For example, it might convert a 5-unit start-stop code to a 6-unit code. The sixth unit or bit in each character interval would be used to signify the start or stop condition.

Synchronous telegraph transmission systems are usually employed to increase the traffic capability of a main route communication channel. An example of this is a time-division-multiplex (TDM) system where characters of several different telegraph messages are sampled in specific timed increments, then sequentially assembled and transmitted over a single line transmission circuit. Code converters are associated with the input/output of the time-division multiple channel transmission equipment. The code converters strip the start-stop elements from the originating start-stop teletypewriter signals, but do not manipulate the five intelligence bits. These bits are passed to the output in the same physical relationship to each other as they were presented to the converter input. The start and stop signals are reconstituted at the receiving terminal.

3.2 Effect of Speed Errors

Synchronous signaling systems do not have start spaces or stop marks; the intelligence is thus contained within a continuous bit stream. However, all the timing problems eliminated by the start/stop approach are inherent characteristics of a synchronous system. These inherent problems are overcome by the use of timing generators (clocks). The codes used in synchronous systems usually contain six information elements and may contain additional elements for error detection and correction (parity bits). Through use of timing generators the system knows the exact bit-rate of the information transmitted. Should a 5 percent timing error occur at the transmitter, not more than 20 bits could be transmitted before transmitter and receiver were apart 100 percent in bit timing. An increase in the timing accuracy by a factor of 100, thus reducing the timing error to 5/100 of 1 percent, would only increase the cumulative error to 2000 bits, which is still prohibitive. Clearly no transmitter-receiver error tolerance can be permitted, since anything but absolute accuracy would eventually cause a malfunction. Thus, two conditions are placed upon the system:

- (a) the receiver must be in exact synchronism with the transmitter, and
- (b) the receiver must keep track of the received bits to determine which grouping constitutes a character.

3.3 Synchronism Techniques

With the development of new techniques to assure the accuracy and stability of timing generators (called clocks, in telegraphy), it is common for systems to remain in synchronism for long periods of time without the need of receiver timing adjustment. Maintaining synchronism usually requires separate circuits called synchronizers. All currently used telegraph systems are synchronized in some manner. The start-stop system synchronizes once each character as compared to synchronous systems whereby the receiving device is automatically adjusted to the signaling rate of the transmitter. The synchronous-telegraphy receiver compares the average repetition rate of the incoming signal transitions to the output of its time base, and adjusts the rate of the time base to be in exact phase and frequency synchronism with the input signal. Although synchronism pertains to both frequency and phase, the usual error in high-stability systems is a phase error. In synchronous systems, the signal is normally a series of binary digits, each representing a bit of information, and each digit may be either mark or space.

In these systems, only a comparatively small amount of correction is necessary once the correct phase relationship has been established. The basic timing has a stability usually in the order of one part in a million or better, and some systems are stable to one part in 100 million. It is not necessarily true that highly stable transmitting and receiving devices will be in synchronism. High stability does imply that if the transmitting and receiving devices are first adjusted accurately to the same time standard, they will remain accurate, within small limits, for long periods of time. High stability also means that once accuracy is adjusted, and synchronism of transmitting and receiving devices is established, the amount of correction required to maintain synchronism is small.

In the practical synchronous telegraph systems, stability is in order of one part in a million per day. The stability is high enough that synchronism can be maintained without correction for as long as an hour or more, provided that the initial adjustment is accurate. Instead of correcting, or resynchronizing after a long period of time, these systems employ correction circuits in the receiving devices, which constantly observe the speed of incoming signal and make small, almost insignificant corrections, as required. Therefore, perfect synchronism is maintained at all times.

Maintaining receiver synchronism with the transmitter requires corrective action for two conditions: first, when slight frequency differences occur between the timing oscillators of transmitter and receiver, and second, when the phase relationships of both oscillator

frequencies do not coincide at the start of the synchronizing process. In the first case, constant correction must be applied to the receiving device throughout the period of operation. In the second case, the receiver is either speeded up or slowed down, until an in-phase relationship is established, after which no further correction is required.

The receiving device must also synchronize on a character basis; i.e., it must complete a character and be in position to start the next character at the same time that the first code element of a new character is received. Further, in time-division-multiplex systems, there must be a channel phasing process so that each character received is retransmitted from the multiplex receiving device during the correct channel interval. Functionally, a synchronizing system may be considered as two parts: the information gathering part and the correction part. Basically, the information gathering part of the system is the part that compares the incoming signal to the local timing to determine whether or not correction is necessary, and if so, the direction (fast or slow) in which correction must be made. The correction part of the system acts upon the information to correct the local timing.

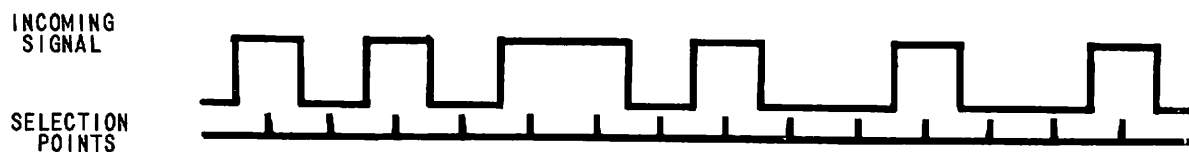
The relationship that may exist between the received signal and the receiver is illustrated in Figure D-1. In part A, the incoming signal is shown as a rectangular, equal interval duration wave. The receiver selection points are shown below, in their optimum positions opposite the center of each signal element. The modulation rates of signal and receiver are equal, and the phase relation is optimum. In part B, the receiver has the wrong modulation rate (5 percent slow). The receiver selection points have a constantly changing relation to the signal, and incorrect operation would result. In part C, the modulation rates have been brought to equality, but the selection points come so late in each element that a moderate amount of distortion will cause errors to be made in selection.

When a synchronous channel is used to interconnect transmitting and receiving start-stop equipment, the start and stop elements of the characters coming from the transmitter are stripped off and are restored at the other end of the synchronous channel, with proper timing. This operation is accomplished with the use of code converters.

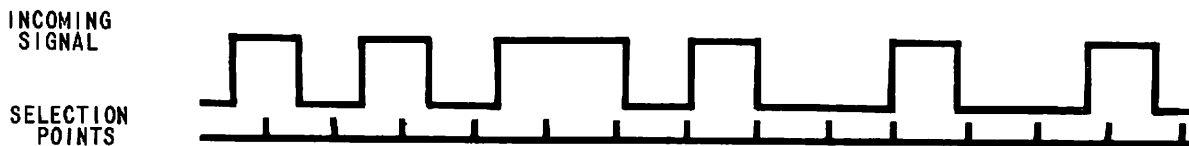
4.0 TELETYPEWRITER SPEEDS

4.1 Description of Speed Ratings

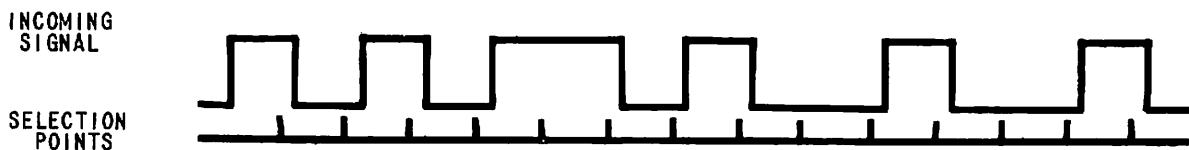
To the user, the operational speed of a transmission system is most intelligible in terms of his needs when expressed in words per minute (wpm) or in characters



A. CORRECT FREQUENCY AND PHASE.



B. INCORRECT FREQUENCY RELATIONSHIP.
RECEIVER 5% SLOW.



C. CORRECT FREQUENCY-INCORRECT PHASE RELATIONSHIP.

TIMING RELATIONSHIP BETWEEN INCOMING SIGNAL AND RECEIVER TIMING
FIGURE D-1

per second. These terms are of little value to the transmission engineer, technical controller, or maintenance technician, unless related to a particular character interval, since the code, interval, and method affect the number of signal elements that must be transmitted per unit interval of time.

In discussing information speed in wpm, the convention is to assume that a word consists of five characters and a space, or six characters per word.

The signal-modulation rate is expressed in terms of the duration of the shortest signal element to be transmitted, since this imposes the most restrictive demand on the bandwidth required for the transmission channel. The modulation rate is expressed in bauds. Numerically, the modulation rate in bauds is equal to the reciprocal of the duration in seconds of the unit interval. Thus, a modulation rate of 50 bauds corresponds to a unit interval of 20 ms (0.020 second).

Studies of operator performance show that the average typing rate is about 60 wpm, but that certain words or word groups (five characters or more) can sometimes be typed as fast as 100 wpm. A speed of about 100 wpm is taken as the Defense Communications System (DCS) standard speed for teletypewriter operation. More precisely, it is 107.1 wpm, when based on a character interval of 7.0 units and a modulation rate of 75 bauds.

The modulation rate can be calculated as follows:

$$\begin{aligned}\text{Modulation rate in bauds} &= \frac{\text{character interval} \times 6 \times \text{wpm}}{60 \text{ seconds per minute}} \\ &= \frac{\text{character interval} \times \text{wpm}}{10}\end{aligned}$$

Or a given modulation rate may be converted to words per minute (wpm):

$$\text{wpm} = \frac{10 \times \text{modulation rate in bauds}}{\text{character interval}}$$

If the machine operational speed is stated in operations per minute (opm):

$$\text{Modulation rate in bauds} = \frac{\text{character interval} \times \text{opm}}{60 \text{ seconds per minute}}$$

4.2 Start-Stop Operation

Table D-1 shows transmitting speeds and related information for the most commonly used 5-unit start-stop printing telegraph code patterns. The term compatibility represents the condition in which two or more codes have identical baud rates and receiving shaft speeds.

There are two main advantages with respect to speed of operation for the CCITT code, shown in Table D-1. First, since no compromises in speed are necessary to obtain practical gear ratios, the 400-operation-per-minute (opm) speed simplifies the gear design when a standard 1800- or 3600-rpm synchronous motor is used to drive transmitting apparatus. Second, the 7.5-unit code pattern simplifies the design of electronic distributors, the use of which is rapidly increasing, as compared to the design using a 7.42-unit code pattern.

The only real advantage of a 7-unit code, as compared to a 7.42- or 7.5-unit code, is the slight increase in character transmitting speed, but the latter code provides greater margin against error in the receiving mechanism.

The four major manufacturers of teleprinters in Europe are Lorenz and Siemens-Halske in Germany, Olivetti in Italy, and Creed in England. All four of these companies employ both the 3- and 4-row keyboards on their teleprinters. The principal manufacturer in the U.S. is the Teletype Corporation. Three-row keyboards have been mainly used in the U.S. Recently, however, 4-row keyboards have been introduced into some commercial teletypewriter systems. An example of this is the 4-row keyboard manufactured by the Teletype Corporation for use in Bell System's Wide Area Data System (WADS) service.

Maximum speeds of European teleprinters generally do not go beyond 100 wpm, while U.S. teleprinters attain speeds as high as 150 wpm. The speed and input signal conditions of representative printing telegraph equipments are presented in Table D-2.

4.3 Modulation Rate Compatibility

The sending and receiving machines in a teletypewriter circuit must be compatible to avoid errors at the receiver. Compatibility represents the condition where start-stop code patterns have identical baud rates and the receiver stops within the character interval of the transmitter. This is to say that a 7.42-unit transmitter can work correctly into a 7.0-unit receiver if the baud rate is the same for each machine.

To explain compatibility, the following situation is illustrated:

In Figure D-2 three transmitters are shown working at different times to the same receiver. Transmitters No. 1 and No. 2 have the same baud rate, but different character intervals. Transmitter No. 3 has a higher baud rate and the same character interval as No. 2.

The same receiver is used in all cases, and the receiver is set to cycle in 6.6-unit intervals, as compared to the 7.42-transmitter-character interval of transmitter No. 1.

TABLE D-1
TRANSMISSION SPEEDS AND TIME ALLOCATIONS FOR
5-UNIT PRINTING TELEGRAPH CODE PATTERNS

Start-Stop Code Pattern (Total No. of Pulses per Character)	Nominal Speeds and Pulse Lengths						Where Used	
	Transmitting Speeds			Pulse Lengths in Milliseconds		Receiving Shaft Speed in RPM		Milliseconds per Character
	Operations per Minute	Average Words per Minute	Baud	Start and Five Code Pulses	Rest Pulse			
7.42 Unit	368*	61.33	45.45	22	31	420	163	Bell System—U.S.
7 Unit	390*	65	45.45	22	22	420	154	Western Union—U.S.
7.5 Unit	400†	66.67	50	20	30	461.5	150	CCITT Standard—Europe
7.42 Unit	404†	67.33	50	20	28.4	461.7	148.4	U.S. Military, for Inter- operation with Allies
7 Unit	428.6†	71.43	50	20	20	461.5	140	Former CCITT Standard—Europe
7.42 Unit	460	76.67	56.88	17.57	25	525.7	130.43	U.S.—All Commercial and Military Users
7.42 Unit	600‡	100	74.2	13.47	19.18	685	100	U.S.—All Users
7 Unit	636‡	106	74.2	13.47	13.47	685	94.3	U.S. Military— Limited Use

*These two codes are compatible.

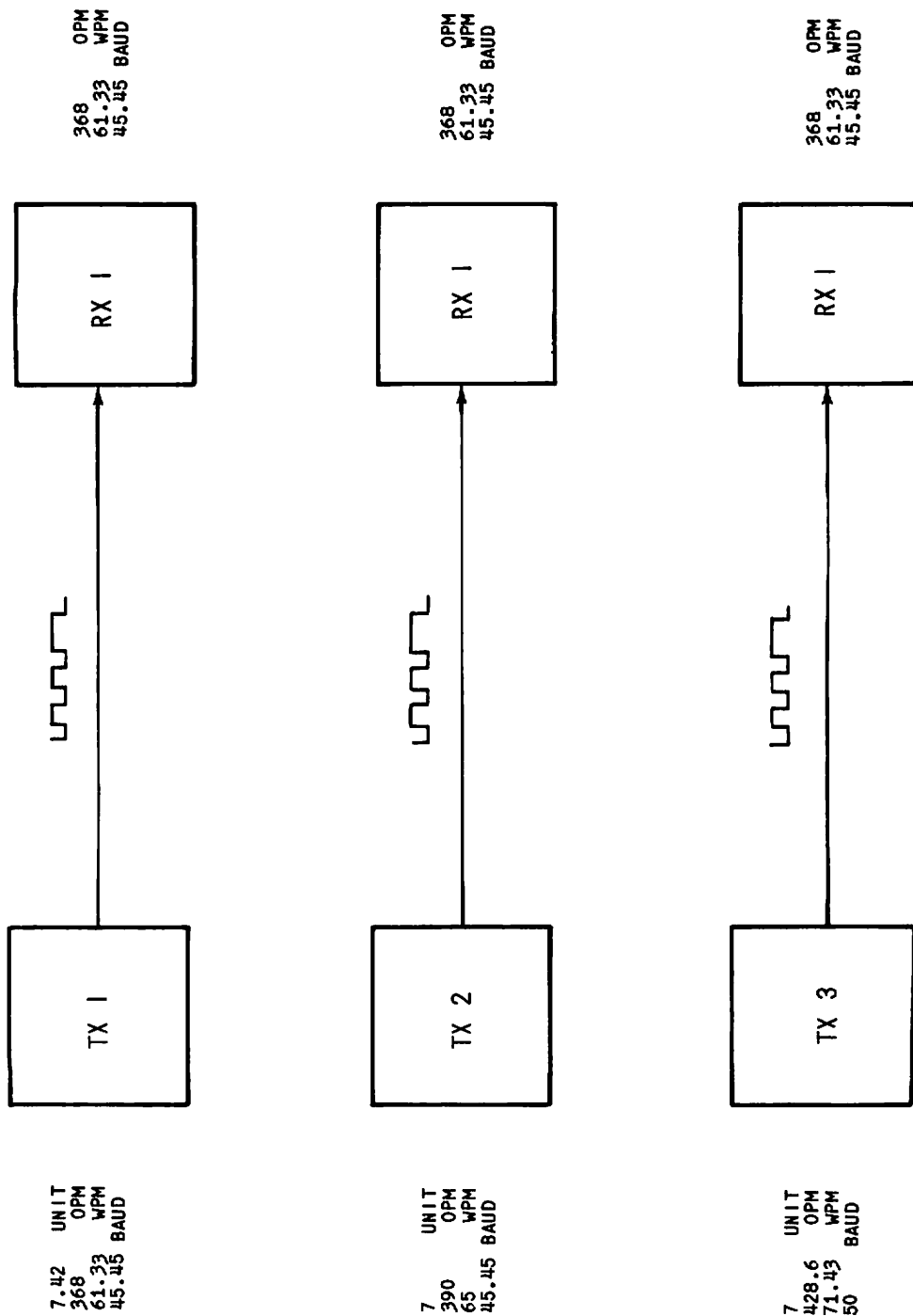
†These three codes are compatible.

‡These two codes are compatible.

**TABLE D-2
REPRESENTATIVE TELETYPEWRITER EQUIPMENT**

Equipment	Type Number		Input Signal	Speeds (wpm)
	Commercial	Military		
Teletype S/R printer	Model 28		20-60 ma	60, 66, 75, 100
Teleprinter S/R printer	Model 105		20-60 ma	60, 75, 100, 125, 150
Teleprinter S/R printer	Model 104A		100 ma, 28 v	60, 75, 100
Kleinschmidt S/R printer	Model 105		20-60 ma, polar	60, 66, 75, 100
Creed S/R printer	Model 75		20 ma dble current 40 ma snl current	60, 66, 100
Intelix S/R printer	Model 15		60 ma polar or neutral	60
Kleinschmidt tape reader	Model 140		10 or 60 ma polar 20 or 60 ma neutral	60, 66, 75, 100
Teletype tape punch	Model 28 LPR		20 or 60 ma	60, 66, 75, 100
Friden tape punch	Model 2		60 ma min	240
Kleinschmidt tape punch	Model 112		20 or 60 ma neutral 15-30 ma polar	60, 66, 75, 100
Printer		TG-7-A	60 ma neutral	60, 66
Teletypewriter		TG-37-B	60 ma neutral	60, 66
Teletypewriter		TT-4/TG	60 ma neutral DC line, 20 ma, VF line unit	60, 66, 100
Teletypewriter		TT-5, 6, 7, 8/FG	60 ma neutral	60, 66

RECEIVER CYCLE =
6.6 UNIT INTERVAL



EXAMPLES OF MODULATION RATE COMPATIBILITY
FIGURE D-2

This allows the receiving shaft to reach its rest position about a half a unit interval before the end of the minimum transmitter stop signal.

In Figure D-3, the representative waveforms of three different transmitters are shown in graphical form, one above the other, and on the same time base. The theoretical waveshape of the letter S (in the teletypewriter 5-unit code) is sent by each transmitter.

The receiver cycle and receiver sampling points are superimposed on the transmitter signals for comparison purposes.

In comparing No. 1 signal with No. 2 signal it is noted that each unit interval has the same pulse length (22 ms), and that stop intervals are 31 ms and 22 ms, respectively. The stop intervals have no bearing on the correct sampling of the information intervals, and since the receiver cycle is stopped ahead of both transmitter stop pulses, it will be synchronism for the start of the next character. Therefore, No. 1 and No. 2 transmitters are compatible with Receiver No. 1.

Transmitter No. 3 has a higher baud rate than transmitters No. 1 and No. 2 and therefore a shorter unit length (20 ms).

In comparing the No. 3 transmitter signal to the No. 1 receiver cycle and superimposing sampling points, it

is noted that the 5th unit interval has been sampled incorrectly, therefore resulting in an error of the received signal. This is because the modulating rate of No. 3 transmitter is sufficiently greater than the No. 1 receiver modulation rate, which results in wrong sampling within the 5-unit intervals. It is apparent that the No. 3 transmitter is not compatible with the No. 1 receiver.

The above example indicates that only the 5th unit interval has been received incorrectly. Each receiver has an adjustable sampling range of 40 percent to either side of the optimum sampling *point*. If there is little bias distortion present in the signal, the range finder may be adjusted to overcome the error in this particular example.

4.4 Reference Chart for Modulation Rates

Table D-3 gives the pertinent technical characteristics of military and commercial communication systems planned or commonly in use. It is intended to serve primarily as a handy reference chart for communicators who must interface with other systems. Definitions and formulas of the various characteristic letter codes are also outlined in Table D-3.

TABLE D-3
REFERENCE CHART FOR MODULATION RATES

1 (W)	2 (C ₁)	3 (M)	4 (B)	5 (N)	6 (U)	7 (SU)	8 (C)	9 (O)	10 (F)
(5 Unit)									
35.71	3.57	25	25	7.0	40	40	200	210.2	75
40.0	4.0	28	28	7.0	35.7	35.7	250	240	84
60	6.0	42	42	7.0	23.8	23.8	166	360	126
65	6.5	45.5	45.5	7.0	21.97	21.97	153.7	390	136.5
66	6.6	46	46	7.0	21.7	21.7	151.9	396	138
71.3 ¹	7.13	49.9	49.9	7.0	20	20	140	427.8	149.73
71.42	7.14	50	50	7.0	20	20	140	428.5	150
75	7.5	52.5	52.5	7.0	19	19	133	450	157.5
100	10.0	70	70	7.0	14.2	14.2	99.4	600	210
106	10.6	74.2	74.2	7.0	13.5	13.5	94.5	636	222.6
107.1	10.7	75	75	7.0	13.3	13.3	93.1	642.6	225
142.7	14.27	100	100	7.0	10.0	10.0	70	858.2	300*
600 ²	60.0	420	420	7.0	2.39	2.39	16.73	3600	1260
40	4.0	29.68	28	7.42	33.6	47.7	249.3	240	89
60	6.0	44.52	42	7.42	22.46	31.9	166.6	360	133.5
61.3	6.13	45.5	42.91	7.42	21.97	31.2	163	367.8	136.5
66	6.6	48.97	46.2	7.42	20.4	28.97	151.3	396	146.9
67.4	6.74	50	47.1	7.42	20	28.4	148.4	404	150
75	7.5	55.65	52.5	7.42	17.97	25.5	133.3	450	166.9
100	10	74.2	70	7.42	13.47	19.1	99.9	600	222.6
101	10.1	75	70.7	7.42	13.33	18.9	98.9	606	225
122.7 ³	12.27	91	85.89	7.42	10.98	31.2	80.5	736	273
60	6	45	42	7.5	22.2	33.3	166.5	360	135
66.7 ⁴	6.67	50	46.69	7.5	20	30	150	400	150
75	7.5	56.25	52.5	7.5	17.6	26.4	132	450	168
100	10	75	70	7.5	13.33	19.99	99.97	600	225
200	20	150	140	7.5	6.66	9.99	49.5	1200	450
600	60	450	420	7.5	1.66	2.49	12.45	3600	1350
800	80	600	560	7.5	1.25	1.87	9.37	4800	1800
1000	100	750	700	7.5	1.0	1.5	7.5	6000	2250
1600	160	1200	1120	7.5	0.625	0.937	4.68	9600	3600
(6 Unit)									
60 ⁵	6	48	48	8.0	20.8	20.8	166.4	360	144
61.3 ⁶	6.13	49.04	49.04	8.0	20.4	20.4	163.2	367.8	147
100 ⁷	10	85	80	8.5	11.76	17.6	99.96	600	255
100 ⁸	10	100	100	10.0	10.0	10.0	100	600	300
8 Unit (synchronous)									
93.75	9.375	75	75	8	13.33	13.33	196.6	562.5	225
187.5	18.75	150	150	8	6.66	6.66	53.3	1125	450
375	37.5	300	300	8	3.33	3.33	26.6	2250	900
750	75	600	600	8	1.667	1.667	13.3	4500	1800
1500	150	1200	1200	8	0.833	0.833	6.66	9000	3600
3000	300	2400	2400	8	0.416	0.416	3.33	18000	7200

TABLE D-3

REFERENCE CHART FOR MODULATION RATES (Continued)

1 (W)	2 (C ₁)	3 (M)	4 (B)	5 (N)	6 (U)	7 (SU)	8 (C)	9 (O)	10 (F)
8 Unit (asynchronous)									
42.9	4.29	45	42.9	10.5	22.2	33.3	233.1	257.4	135
53.3	5.33	56	53.3	10.5	18.7	28.1	196.3	319.8	168
71.4	7.14	75	71.4	10.5	13.33	19.99	140	428.4	225
142.8	14.28	150	142.8	10.5	7.0	10.5	73.5	856.8	450**
429	42.9	450	429	10.5	2.33	3.49	24.4	2574	1350
571	57.1	600	571	10.5	1.66	2.49	17.4	3426	1800
714	71.4	750	714	10.5	1.33	1.99	13.9	4284	2250
1143	114.3	1200	1143	10.5	0.833	1.24	8.7	6858	3600
1333	133.3	1400	1333	10.5	0.714	1.07	7.488	7998	4200#

NOTES:

¹Telex-Europe²TTY Elec. Dist.³Teletype Duplex.⁴CCITT Standard.⁵IBM Start-stop.⁶Teletypesetter.⁷Stock Ticker.⁸IBM Start-stop

** Typical capability of the AN/FGC-61, AN/FGC-29, etc. (about 50 cards per minute).

Typical 100 cards per minute.

* Permissive standard rates.

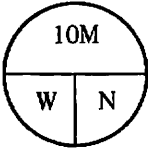
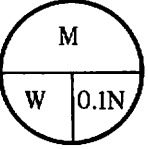
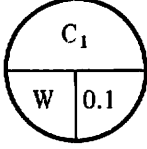
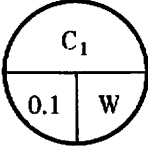
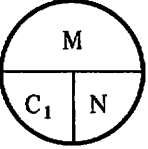
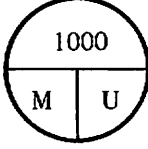
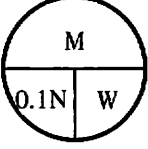
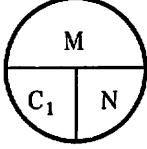
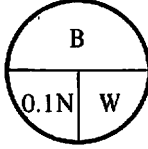
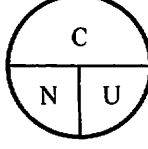
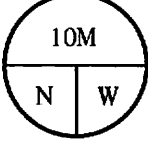
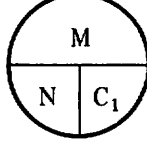
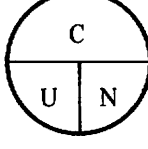
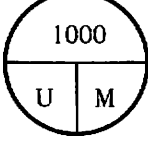
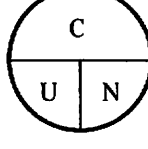
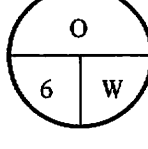
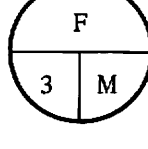
Bold face type indicates preferred standard rates.

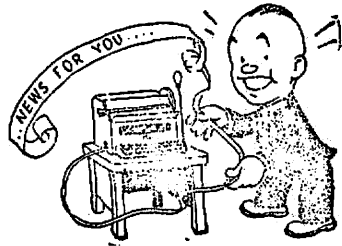
Definitions

1. (W) = Words per minute.
2. (C₁) = Characters per second.
3. (M) = Modulation rate (Baud).
4. (B) = Bits per second.
5. (N) = Units per character interval, or unit intervals, or character interval.
- 5a. (N₁) = Whole bits per character interval.
6. (U) = Unit interval (size in milliseconds).
7. (SU) = Duration of stop interval in milliseconds.
8. (C) = Character intervals (size in milliseconds).
9. (O) = Operations per minute.
10. (F) = Normal bandwidth to pass 5th harmonic, (rounded out from a factor of 2½ to a factor of 3) in cycles per second.

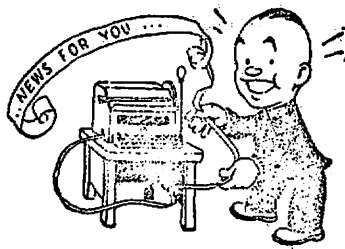
TABLE D-3
REFERENCE CHART FOR MODULATION RATES (Continued)

FORMULAS

1. $W = 10M/M$		$= M/0.1N$		$= C_1/0.1$	
2. $C_1 = 0.1W$		$= M/N$			
3. $M = 1000/U$		$= 0.1NW$		$= C_1N$	
4. $B = 0.1N_1W$					
5. $\dot{N} = C/U$		$= 10M/W$		$= M/C_1$	
6. $U = C/N$		$= 1000/M$			
7. $C = UN$					
8. $O = 6W$					
9. $F = 3M$					



PART E
THE TELETYPEWRITER SIGNAL



Part E

The Teletypewriter Signal

1.0 TELEGRAPH SIGNAL WAVESHAPES

1.1 General

Electrical pulses must be first formed by the transmitting device; second, efficiently transmitted through a connecting medium, and finally received and interpreted by the receiving device to determine whether the received message is identical with the original. However, owing to the electrical characteristics of telegraph circuits and associated apparatus, telegraph signal currents are always more or less modified (electrically) in transmission. These modifications or distortions may cause errors in the received message, if suitable corrections are not made.

Telegraph signals in DC operation are classed as neutral (current flows over the line in either direction for the marking position, and no current flows for the spacing position of the line relays) or polar (current flows over the line in one direction for the marking and in the opposite direction for the spacing position of the line relays). For either type of signal, the change of current from mark to space (or space to mark) is known as a transition.

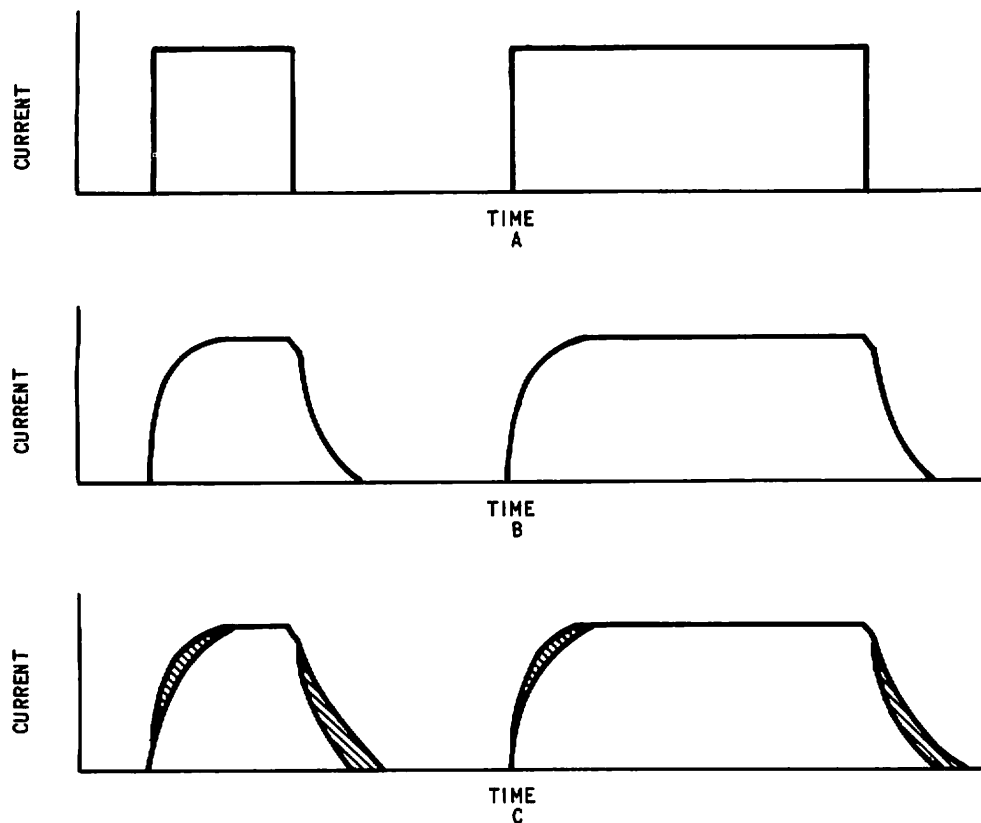
1.2 Waveshapes in Neutral Systems

Ideally, the DC telegraph signals received over a transmission line should be exactly the same as the signals sent. Thus, we may assume that the Morse code signal for the letter A, made by opening and closing a telegraph key, has the waveshape shown in Figure E-1, A. If the transmission line were purely resistive, the received signal would have the same waveshape, except for some decrease in the current caused by the IR drop in the line. For very short loops, or connections within a central office, this situation may be closely approximated. However, loops more than two or three miles in length, and practically all line circuits, contain enough inductance and capacitance to affect the signal waveshape materially. When the key is closed, the presence of inductance causes the current to build up on a sloping

curve, from zero to the maximum value, as shown in Figure E-1, B. It also slows down the current fall-off when the key is opened. Capacitance in the circuit tends to reshape the wave further, as indicated by the shaded portions in Figure E-1, C. Insertion of inductors and capacitors, as in composite sets or similar apparatus, naturally increases the extent of the waveshaping still more.

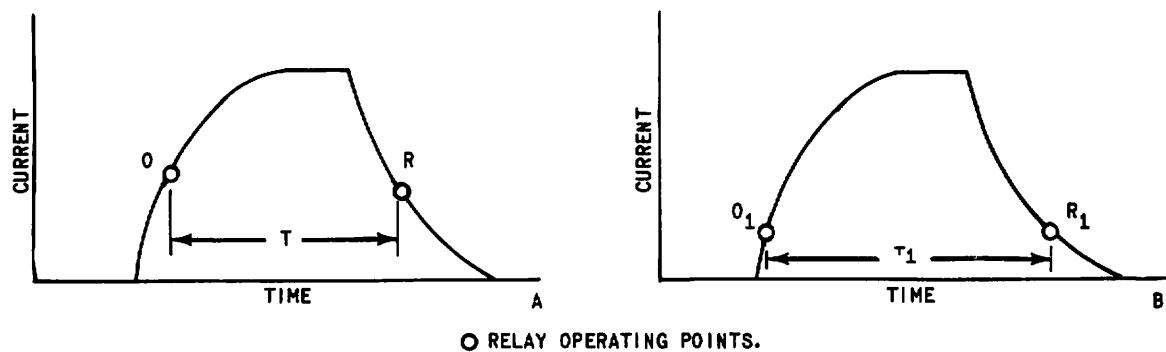
The basic significance of the signal waveshape, from the viewpoint of telegraph transmission, may be understood by considering its effect on signal reception with a simple neutral relay. This relay may be adjusted to operate at any one of a considerable range of current values and to release at corresponding lower values of current. If a received signal wave is essentially square, as in Figure E-1, A, the relay will operate and release at the same time regardless of its adjustment. However, the wave is not usually square, and the time length of the received signal is definitely affected by the relay adjustment. In Figure E-2, A, the relay is adjusted to operate at time O and to release at time R; the length of the received signal is then presented by T. If the adjustments are then changed to permit operation at O_1 and release at R_1 , as in Figure E-2, B, the length of the signal is increased to T_1 . In telegraph parlance, the signal is now "heavy." Adjustment of the relay in the opposite direction would have shortened the signal, or made it "light." These two conditions are called marking bias and spacing bias, respectively. Either type, if of sufficient magnitude, may make it difficult to read the received signals accurately.

The effect of signal waveshape on bias may be more critically analyzed by considering neutral transmission employing polar relays. Figure E-3 is a schematic drawing of a neutral telegraph circuit using electrically biased polar relays. The armature of the polar relay is held in the spacing position by a constant current in its bias winding instead of by a spring, as in the neutral relay. Normally, the bias current is set at a value equal to one-half of the full line current when marking. In Figure E-4, which again represents a waveshape for the Morse



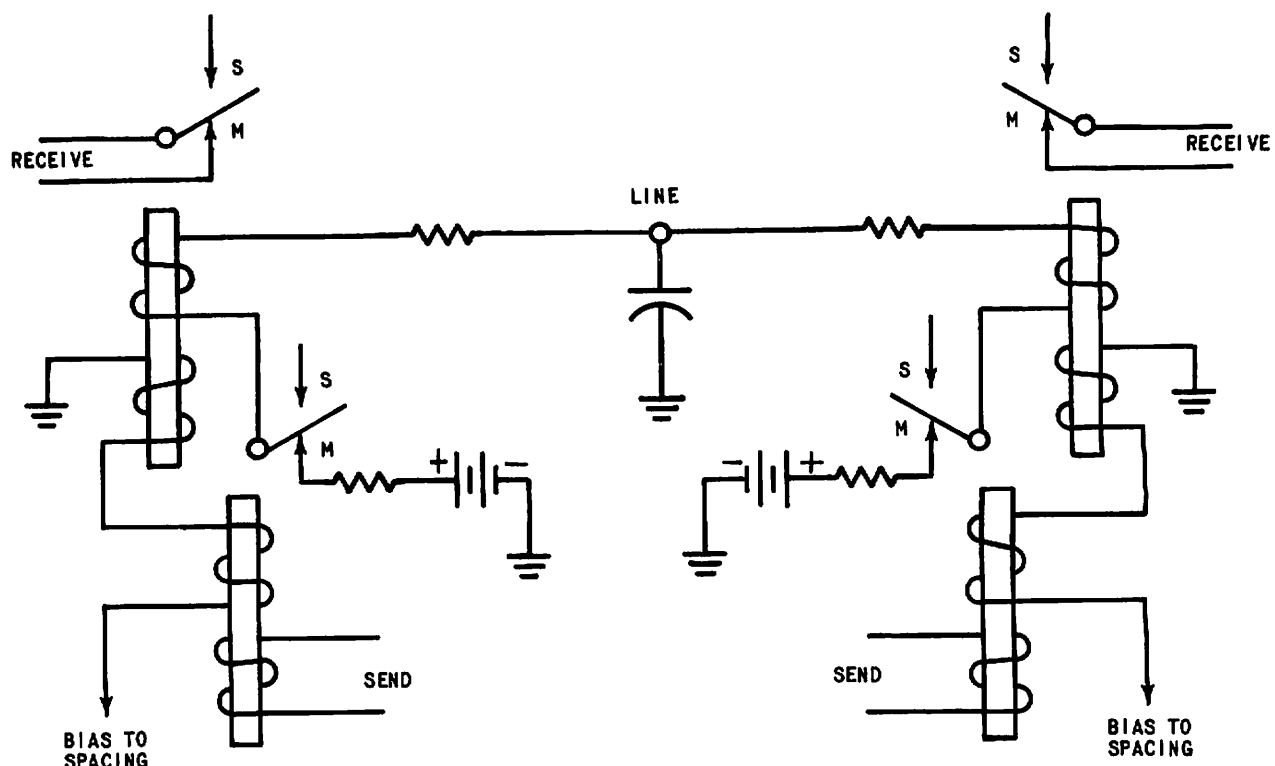
*(From Principles of Electricity as Applied to Telephone and Telegraph.
Used by permission of American Telephone and Telegraph.)*

**EFFECT OF INDUCTANCE AND CAPACITANCE ON TELEGRAPH WAVESHAPE
FIGURE E-1**

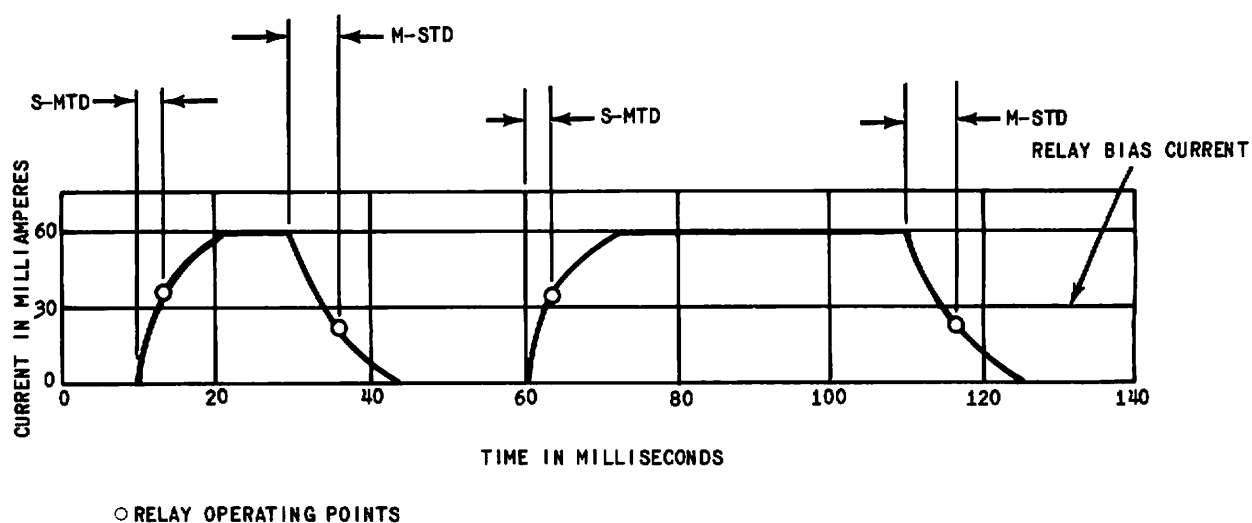


*(From Principles of Electricity as Applied to Telephone and Telegraph.
Used by permission of American Telephone and Telegraph.)*

**EFFECT OF RELAY ADJUSTMENT ON TELEGRAPH SIGNAL LENGTHS
FIGURE E-2**



HYPOTHETICAL TELEGRAPH CIRCUIT USING BIASED RELAYS
FIGURE E-3



SIGNAL WAVESHAPES IN HYPOTHETICAL CIRCUIT OF FIGURE E-3
FIGURE E-4

A, the full line current is 60 milliamperes (ma), and the current in the bias winding is 30 ma. If the relay polepieces are properly adjusted, so that both marking and spacing poles are equidistant from the armature, the armature is free to move to its marking position as soon as the current in the line winding reaches a value slightly greater than 30 ma. Similarly, the armature returns to the spacing contact as soon as the line current decreases slightly below 30 ma.

When the signal waveshapes are curved as shown, any change from normal in the bias-winding current value, in the full line current value, or in the polepiece adjustments, may change the length of the received signals. For example, a reduced value of relay bias current causes the operate and release points to move downward on the signal curve with resultant marking bias. The same effect appears if the marking pole is adjusted too close to the armature, or the spacing pole too far away. On the other hand, poor adjustment of the polepieces in the opposite direction, or too high value of relay bias current causes light signals or spacing bias. Higher than normal line current produces marking bias while low line current results in spacing bias.

In addition, either marking or spacing bias may be caused by the inherent characteristics of the transmission circuit, even though all relay adjustments and current values are normal. This results from a different curvature in the leading and trailing edges of the signal pulse. (Refer to Figure E-4.) It will be noted that there is a definite interval between the time the circuit is closed and the time the relay operates, because of the curvature of the rising current wave. This interval, which may range from a fraction of a millisecond to several milliseconds, is called a space-to-mark transition delay and abbreviated S-MTD. Conversely, when the circuit is opened, there is a mark-to-space transition delay (M-STD) as the current falls off from maximum value to the relay release point. The length of each delay is determined solely by the shape of the current wave. If the two delays are equal in length, the signal length is not affected and the circuit introduces no bias. If the M-STD is greater than the S-MTD, all marks are lengthened accordingly and all spaces shortened the same amount. The circuit thus causes marking or positive bias. Conversely, if the S-MTD is longer than the M-STD, all spaces are lengthened and marks shortened to produce spacing or negative bias.

For a given signal, as shown in Figure E-4, it is possible to measure the transition delay time or the extent of bias in milliseconds (ms). However, because several different signaling speeds are employed in telegraph practice, it is generally more useful to measure bias as a percentage of the unit-signal element or pulse. Thus,

the unit pulse in 600-wpm speed teletypewriter operation is 22-ms duration. A positive bias of 20 percent in this case would lengthen marking signals by 4.4 ms. If transmission were at 100-wpm speed where the unit signal length is 13.5 ms, the same percentage bias would lengthen the signals by 2.7 ms.

It is evident that the inherent design of neutral signaling causes different curvatures in the leading and trailing edges of the signal pulse. The S-MTD and the M-STD will never be equal and spacing or marking bias will always be present to some degree.

Neutral loops must be kept short, as line capacitance will decrease the line current and tend to distort the waveshape, thus increasing the bias beyond the receiving instrument tolerances. The severe bias condition will cause false operation of the receiving equipment.

1.3 Waveshapes in Polar Systems

Waveshapes in polar telegraph systems are affected by circuit inductance, capacitance, and leakage the same as in neutral telegraph systems. Figure E-5 shows a simple one-way polar telegraph circuit, arranged to send -130- and +130-volt pulses from the central office (sending point) to an outlying receiving point, which has series line resistance and capacitance between the line and ground.

Assuming that the sending-end connections are adjusted to provide normally steady-state line currents of +35 ma (marking) and -35 ma (spacing), as shown in Figure E-6, the line capacitance to ground will delay the change of line current from spacing to marking (S-M transition) and from marking to spacing (M-S transition).

The M-S and S-M waveshapes are identical in form and symmetrically located about the zero line. The S-MTD and the M-STD are equal. Since the sending-end potentials are equal and of opposite polarity, the circuit resistance remains constant for both positions of the sending relay armature, and the operating points of the receiving relay are symmetrically located at about the middle of the waveshapes; therefore, the received polar signals are unbiased.

In polar systems, as in other circuits, the M-S transition and S-M transition are delayed because of the capacitance between the wires. When the line current is marking, the voltage on capacitor C (Figure E-5) is positive, and when the line current is spacing, the voltage on this capacitor is negative. The line current change from marking to spacing then involves a voltage change on the line capacitance from a positive value through zero to a negative value. The capacitor discharge current flows through the receiving relay in the same direction

as the line current and helps to sustain it. The capacitor is then charged by current shunted away from the receiving-relay winding; therefore, the buildup of line current in the receiving-relay windings is delayed. These two actions combine to make marking to spacing line current transitions gradual as shown in Figure E-6.

With true polar transmission, the probability of bias distortion of signals is substantially reduced. The ideal waveshape for such operations is illustrated in Figure E-6. These marking and spacing waves are identical in form. If, in addition, the positive and negative line currents are equal in value, and all relays are adjusted to operate and release at approximately the middle of the wave, the mark-to-space transition delays must always be exactly the same as the space-to-mark delays. Under these conditions, transmission is completely free from bias. However, it is necessary to note that relays in polar systems can get out of adjustment as readily as those in neutral systems. It is also possible for differences in ground potential between the terminals of a circuit to cause unequal values of marking and spacing line currents. Thus, either effect will unbalance the transition delays, and thus produce bias.

In either neutral or polar operation, any bias present is a constant whose value is determined by the inherent characteristics of the line circuit and equipment associated with it. Bias distortion affects all signals, regardless of their length, in exactly the same way and in exactly the same amount. Bias is always undesirable, and when severe enough, it will cause false operation of receiving equipment. Unless the curvature of the waveshape is too extreme, bias can usually be kept within satisfactory working limits by corrective relay adjustments.

2.0 SIGNAL DISTORTION

2.1 Definition

Any deviation of a signal parameter (time, amplitude, or waveshape) from that of the ideal signal is considered as distortion. In telegraphy, timing is a prime requisite, and excessive wrong timing is a form of distortion that could cause error in most binary systems. In the binary system only one of two stable conditions can exist at any instant, and the receiving device is required to detect either state within specific time increments. Therefore, for accurate operation, it is imperative that the signal element arrive at the receiving device at precisely the correct instant. Any excessive displacement in time of a signal element, from the interval of time it should occupy, is considered as a form of distortion.

2.2 Components of Distortion

Telegraph distortion due to different causes requires different treatment for proper control in both design and maintenance work. The relationship of various distortion components is shown in Figure E-7 and each type is discussed separately below.

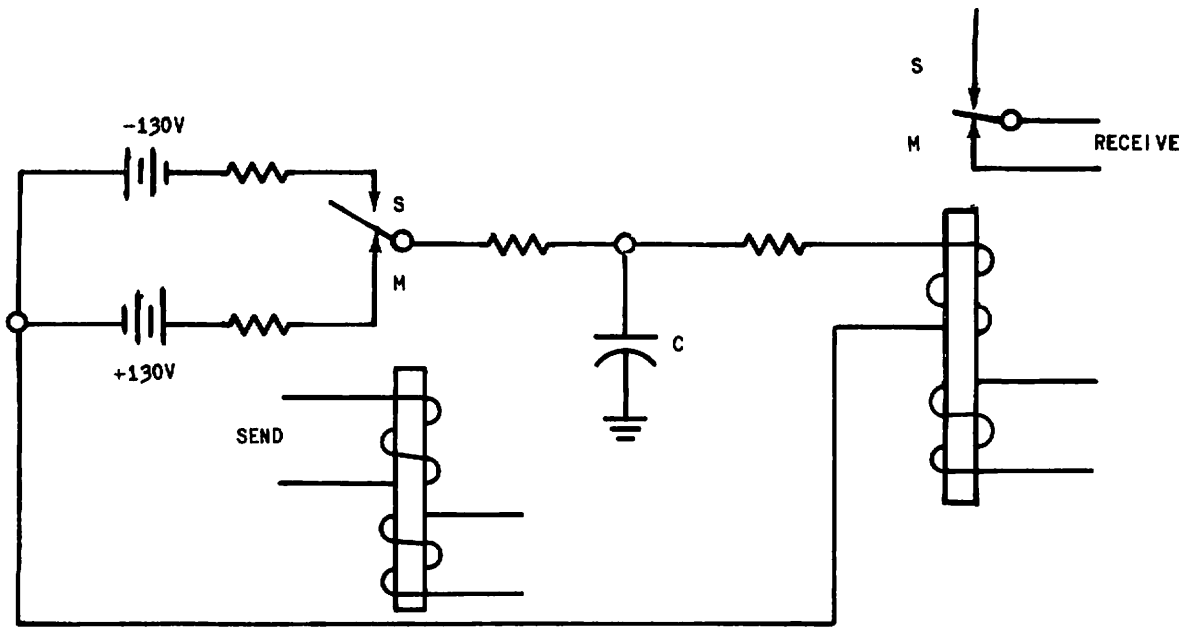
2.2.1 Total Distortion. The overall or total resultant distortion of signals for a given telegraph circuit consists of two principal types, i.e., systematic and fortuitous.

Assume that a given telegraph character is sent continuously over a telegraph circuit, and that each repetition of the character is considered perfect as sent. Measurements of the distortion of each of the unit marks (elements) in a large number of successive repetitions of the character at the receiving end will generally indicate that the distortion differs from element to element in a given repetition of the character, and from character to character for a particular element in the character. The average of a large number of distortions for a particular element is designated as systematic distortion. The individual departure of the distortion from the average of a given measured distortion is designated as fortuitous distortion. The total distortion of each signal element is the algebraic sum of the systematic and fortuitous distortions, and is the amount of deviation between the sent and received signals.

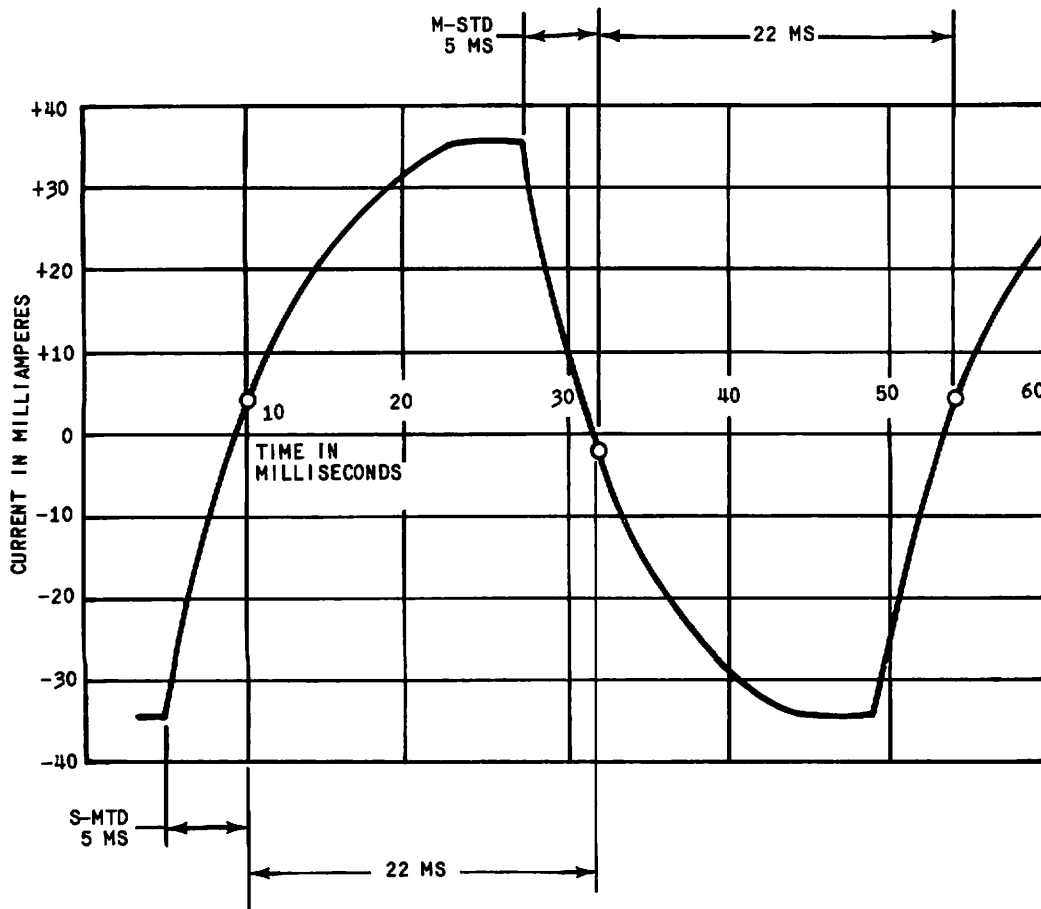
Systematic distortion may be subdivided into bias, characteristic, cyclic, end, and peak distortion. These components, together with fortuitous distortion, are discussed in the following paragraphs.

2.2.2 Bias Distortion. Bias distortion is the uniform lengthening or shortening of the mark or space elements, one at the expense of the other (Figure E-8, parts A, B, and C). The lengthening of the marking elements is called marking bias distortion, and the lengthening of the spacing elements is called spacing bias distortion. The degree of bias distortion is expressed as a percentage of the unit interval. In start-stop operation, bias appears as the displacement of the space-to-mark transitions with respect to the initial mark-to-space transition of the start element. These transitions are advanced if the bias is marking, and delayed if bias is spacing.

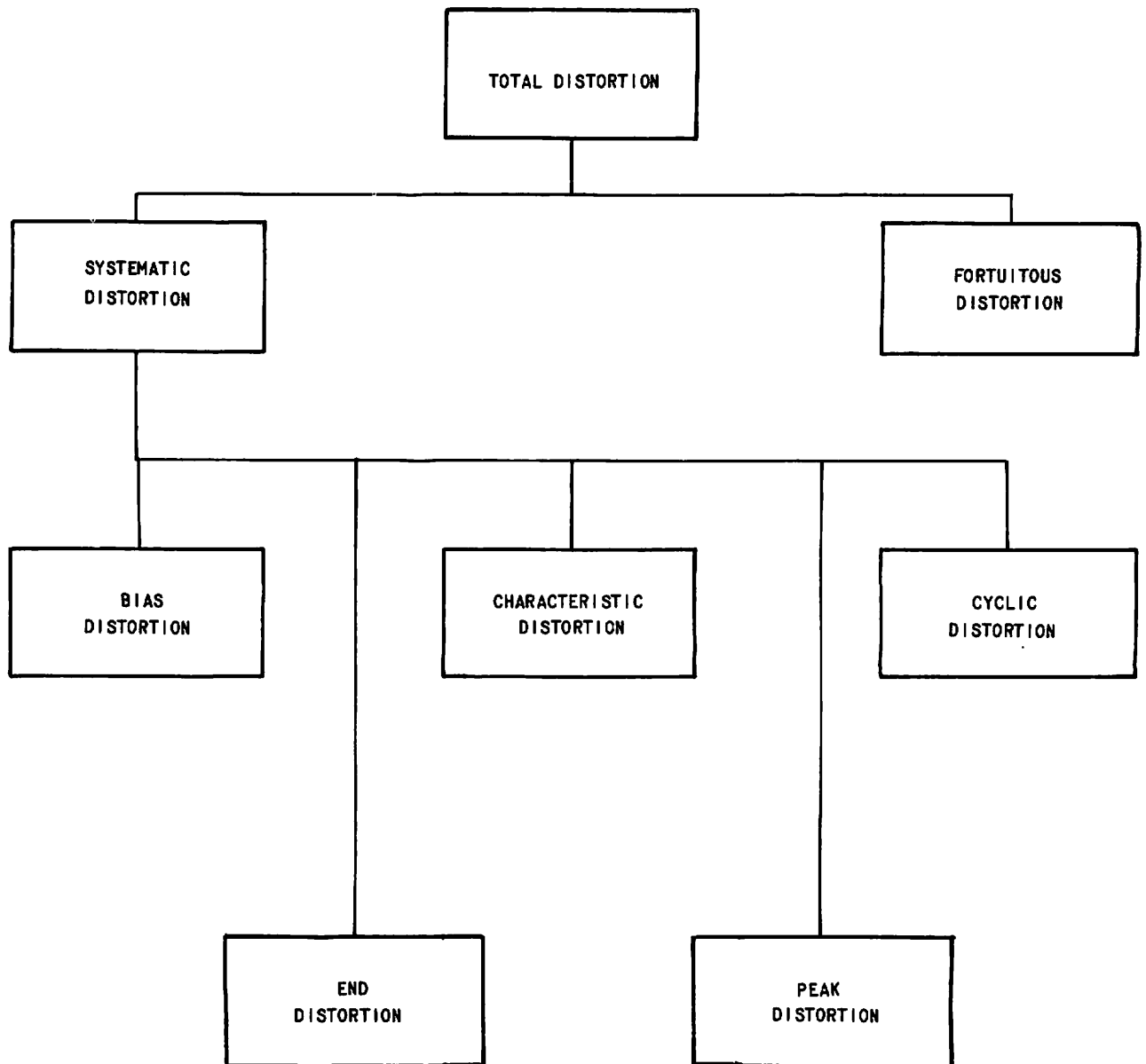
The nature of bias distortion is such that interchanging the functions of the two current values will change the sign of the systematic distortion, but not its magnitude. In a polar telegraph system, in which marks and spaces are sent by means of currents equal in magnitude but opposite in sign, systematic distortion may be caused by unequal voltages at the transmitting end. If the positive voltage is greater than the negative voltage, the circuit causes the marks to be lengthened when positive



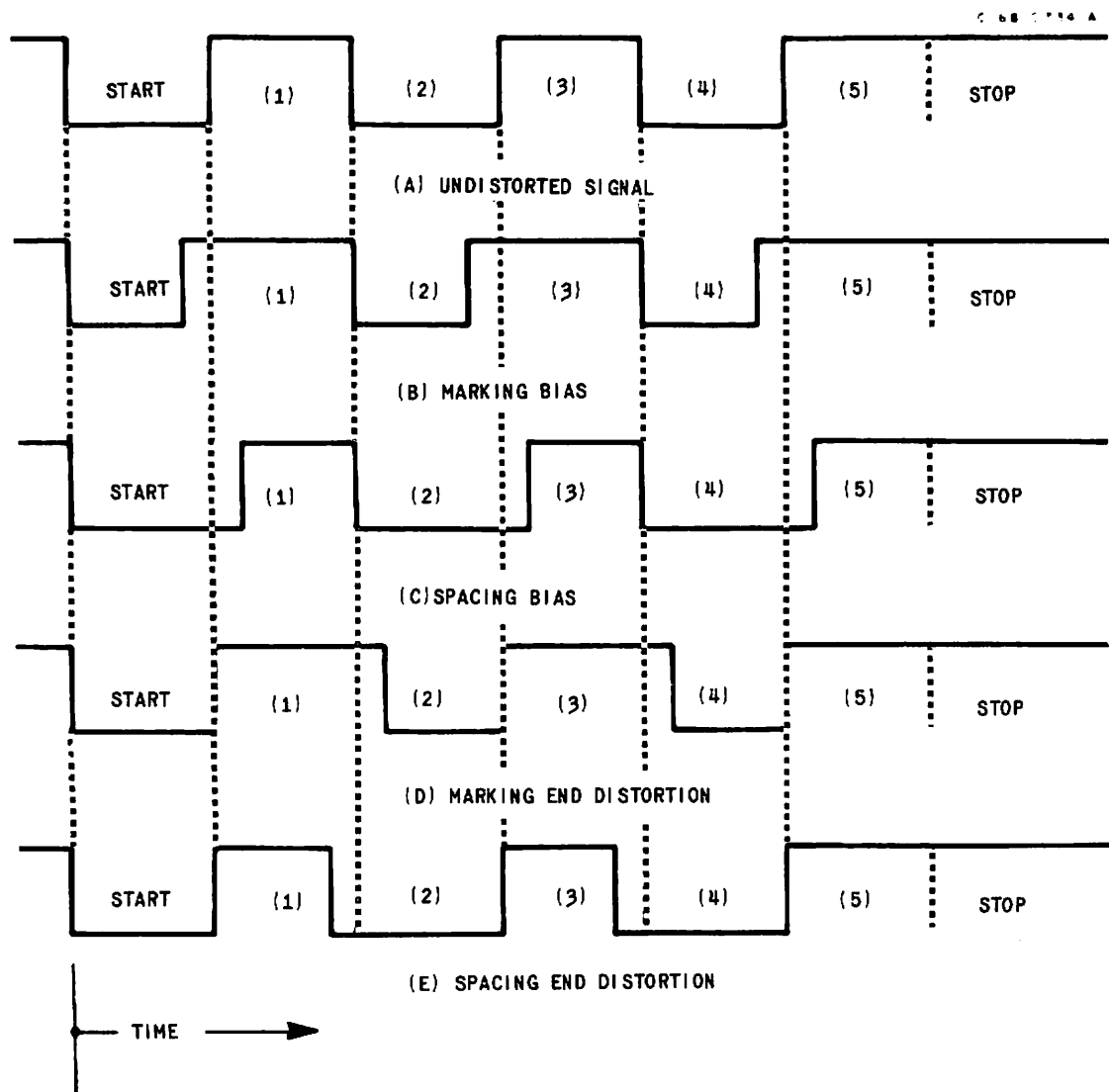
POLAR TELEGRAPH CIRCUIT, SIMPLIFIED SCHEMATIC DIAGRAM
FIGURE E-5



SIGNAL WAVESHAPES IN POLAR TELEGRAPH CIRCUIT
FIGURE E-6



COMPONENTS OF TELEGRAPH SIGNAL DISTORTION
FIGURE E-7



**TYPES OF SIGNAL DISTORTION
FIGURE E-8**

current is used for transmitting marks. Conversely, rearranging the system so that negative current is used for transmitting marks will cause the marks to be shortened proportionately. In systematic distortion, interchanging the functions of the two current values employed changes the sign of the systematic distortion, but not its magnitude. The distortion is called bias because a lack of symmetry in the circuit is indicated.

Some of the more common causes of bias are improperly adjusted relays, earth potential differences, leakage currents, unbalance of artificial line on repeaters, and unequal battery tap resistance or potentials. Bias will affect both the beginnings and the ends of received signal elements, but since the teletypewriter receiving mechanism starts on a mark-to-space transition affected by the same bias, succeeding mark-to-space transitions will not be displaced with respect to the start transition. However, the space-to-mark transitions will be displaced with respect to the start transitions by an amount corresponding to the total amount of bias. Marking bias will cause all space-to-mark transitions to be uniformly displaced with respect to the start transitions by an amount corresponding to the total amount of bias. Marking bias will cause all space-to-mark transitions to be uniformly displaced toward the start pulse, and spacing bias will cause them to be uniformly displaced away from the start pulse.

2.2.3 Characteristic Distortion. Characteristic distortion is the displacement of signal transitions resulting from the persistence of transients caused by preceding transitions.

This characteristic distortion results from various causes, which are usually different from those associated with bias distortion. Assume a telegraph system, in which the sending battery potentials are equal and opposite in sign, and the marks and spaces are formed by corresponding currents, equal but opposite in sign. Also, owing to the characteristics of the given system, the current is slow in building up to the normal mark or space value. If the current does not have time to reach its final value on the short-signal elements, the first mark following a long space may be shortened.

In this case, interchanging the functions of the positive and negative currents will not alter the sign or the magnitude of the resulting distortion, since the first mark will be shortened whether it is formed by means of a positive or a negative current. This type of distortion is determined by the electrical, magnetic, and mechanical characteristics of the circuit, which are fixed by design.

Characteristic distortion may displace both the received space-to-mark and mark-to-space transitions with

respect to the start signal, depending on the signal combination, and always recurs for the same signal combination. Accordingly, it may affect both ends of the teletypewriter orientation range, and it is not practicable to distinguish between the characteristic and fortuitous components of distortion when miscellaneous characters are being received.

A tabular listing of the differences between bias and characteristic distortion is given in Table E-1.

2.2.4 Cyclic Distortion. Cyclic distortion, which is neither characteristic, bias, nor fortuitous, has a periodic character that originates from some defective or improperly adjusted device in the circuit, e.g., induction from power systems, etc. Cyclic distortion values, when included with other distortion components, should not exceed the margin allowances required for the receiving teletypewriters. This condition is illustrated in Figure E-9, parts A and B.

2.2.5 Fortuitous Distortion. The fortuitous component of distortion is the individual departure of any one distortion from the average (systematic) distortion of a particular element in a large number of successive repetitions of a signal. It displaces miscellaneous received transitions by various amounts in an irregular manner, regardless of the signal combination. At times it may be large enough to cause a complete failure of the circuit, or the addition of fortuitous distortion to the systematic distortion already in the circuit may result in an error in the received character. This type of distortion is common in high frequency radio circuits where disturbances in the transmission media cause irregular reception of signals. Other causes are accidental irregularities in the operation of the apparatus and moving parts, power induction, momentary battery fluctuations, and line hits.

2.2.6 End Distortion. In start-stop operation, end distortion is the shifting of the end of all marking pulses from their proper positions in relation to the beginning of the start pulse (Figure E-8, parts D and E).

If the mark-to-space transitions are delayed, the effect is to lengthen the marking pulses and shorten all spacing pulses. This type of distortion is called marking-end distortion. If the mark-to-space transitions are advanced, the effect is to shorten the marking pulses and lengthen all spacing pulses. This is called spacing-end distortion. It is an artificial sort of distortion, usually deliberately produced for maintenance purposes by a test signal generator.

2.2.7 Peak Distortion. Peak distortion defines the maximum displacement of signal train transitions occurring during a measuring period. It does not imply that all signals are distorted by this same maximum value. Peak distortion is illustrated in Figure E-9, part C.

TABLE E-1
DIFFERENCES BETWEEN BIAS AND CHARACTERISTIC DISTORTION

Type of Distortion is Affected by	Type of Distortion	
	Bias, ms	Characteristic
1. Length of signal	No	Yes
2. For a given length of signal, whether the signal is marking or spacing	Yes	No
3. Amount and arrangement of the circuit capacitance, inductance, and resistance.	No, except in neutral operation	Yes
4. Unequal marking and spacing line currents. Change in line current. Change in receiving relay bias current. Ground potential difference between sending and receiving end.	Yes	No
5. Speed of transmission	No	Yes
6. Usual operating variations, occurring frequently throughout the day, such as voltage fluctuations and relays requiring adjustments.	Yes	Not appreciably

2.3 Teletypewriter Margin

The teletypewriter itself is equipped to measure systematic distortion within certain limits. The limits of a receiving instrument to accept distorted signals, and yet still produce perfect registration of the desired character, is called the margin of the teletypewriter. The maximum theoretical margin that it would be possible to attain in a perfectly designed receiver is 50 percent; this implies that the selection of each character element would have to occur in an infinitely short time at the middle of each element. In practice, start-stop machines give a margin of 40 to 45 percent.

Figure E-10, part A, illustrates the sequence of circuit conditions produced by the sending mechanism in transmitting the letter R. The shaded areas represent the intervals during which the circuit is closed, and the blank sections the intervals during which the circuit is opened by the sending device. The received signals shown in part B have the same time lengths as those produced by the sending distributor of part A. The solid blocks superimposed upon the received signal represent those parts of the signal that are used by the selecting mechanism at the receiving machine.

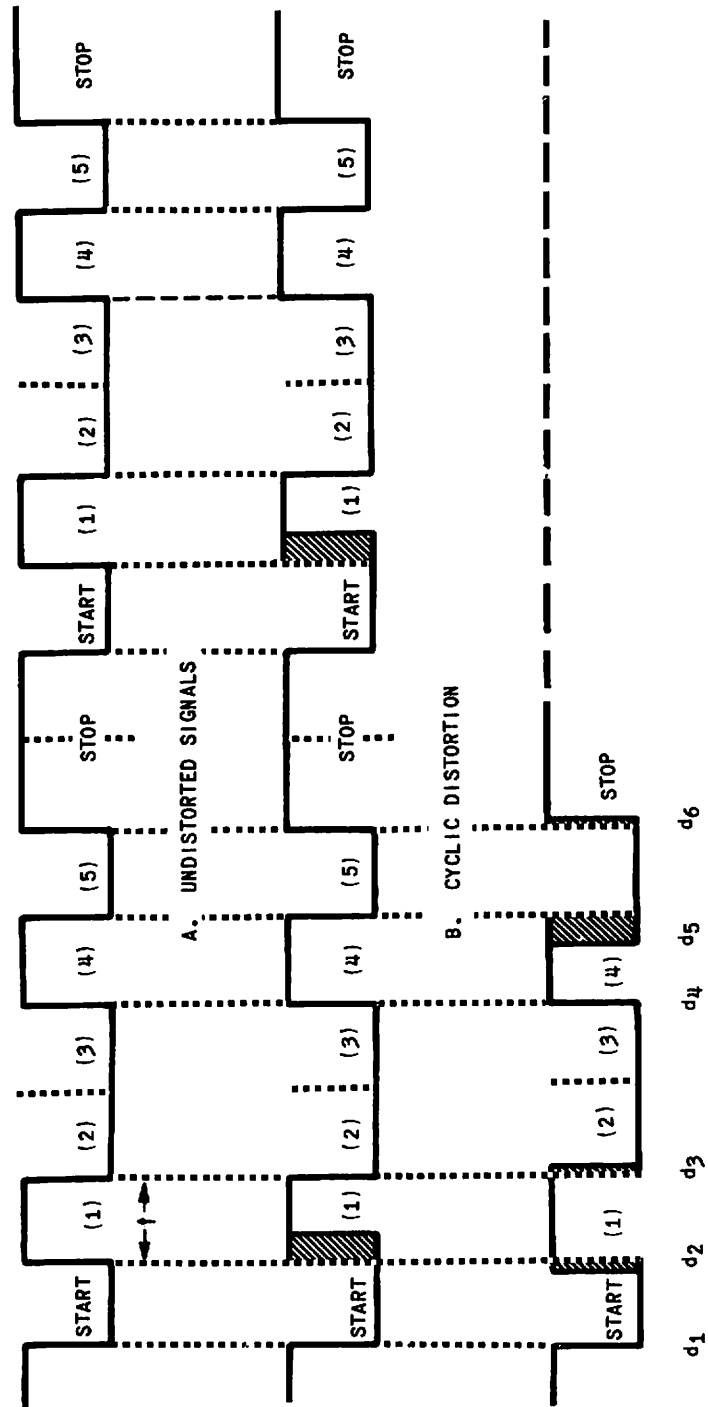
When correctly oriented the selecting mechanism normally operates only during the central portion of

the received signal pulse, and requires only about 20 percent of the unit interval.

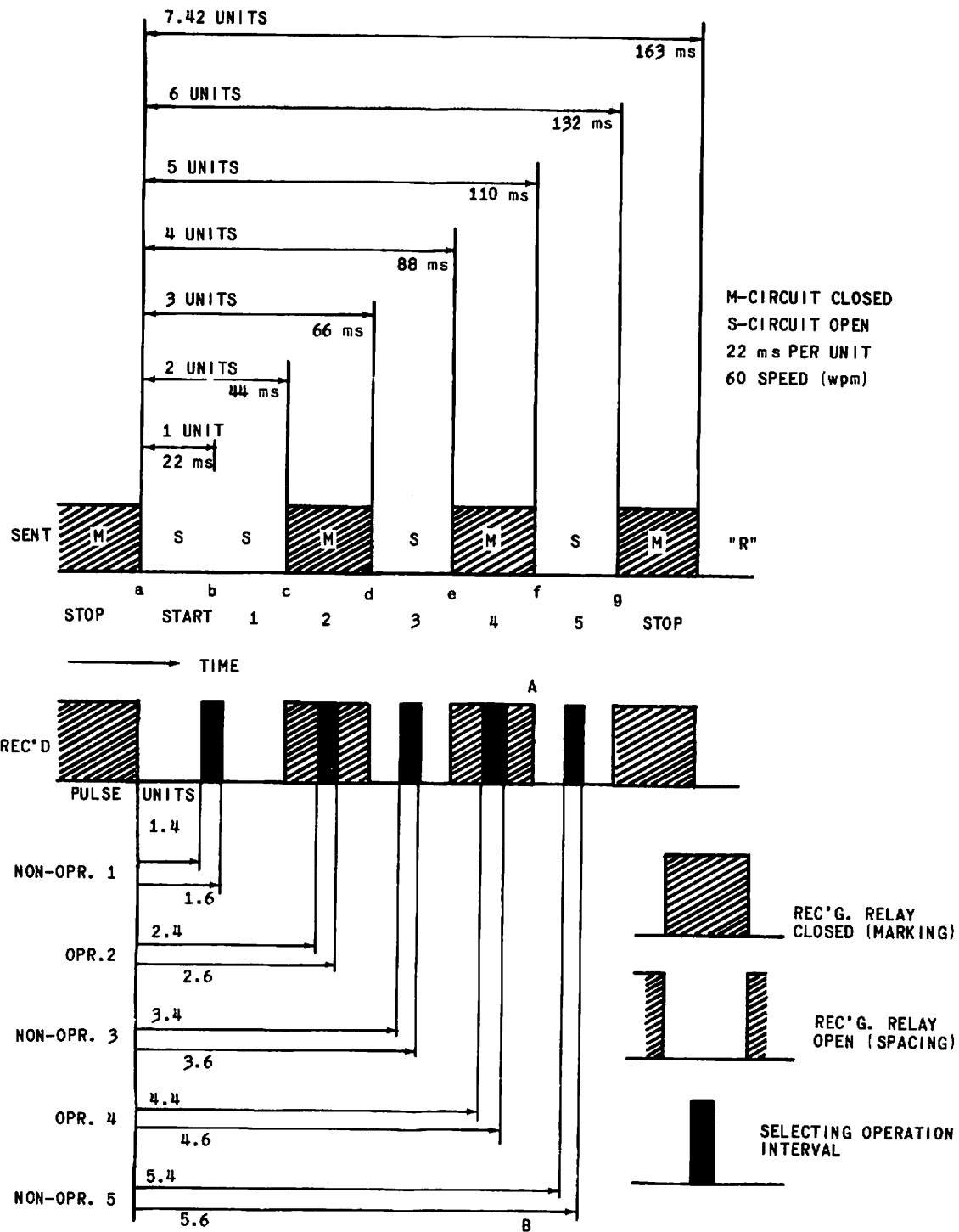
For the transmission of letter R (part A) there are mark-to-space transitions at points a, d, and f, and space-to-mark transitions at points c, e, and g.

For the ideal signal intervals shown, the transitions occur midway between the selecting blocks. The time length from the edge of each selecting block to the adjacent transition is four-tenths of a unit interval, which indicates that the transitions may be shifted towards the selecting blocks as much as 40 percent of the length of a unit interval before an error is recorded on the machine. Any deviation from the ideal positions for the occurrence of transitions represents distortion, and may be measured in terms of its percentage of a unit interval. The ideal situation is for the selecting segments of the receiving selector, which are one-fifth the length of the unit segments in the sending mechanism, to be at mid-position with respect to the sending units. Under these conditions, the transitions may be shifted as much as 40 percent in either direction before an error is recorded on the machine.

The receiving unit of the teletypewriter is equipped with a mechanism whereby the latch assembly may be mechanically moved through an arc corresponding to



DISTORTED TELEGRAPH SIGNALS ILLUSTRATING CYCLIC AND PEAK DISTORTION
FIGURE E-9



(From Principles of Electricity as Applied to Telephone and Telegraph.
Used by permission of American Telephone and Telegraph.)

SEQUENCE OF CIRCUIT CONDITIONS IN SENDING AND RECEIVING THE LETTER "R"
FIGURE E-10

the length of a unit segment. By this means, all the selecting segments may be shifted with respect to the beginning of the start segment over a scale range equal to a unit segment (22 ms for 60-wpm speed). This mechanism is known as a range finder, and is equipped with a scale graduated from 0 to 120, as indicated in Figure E-11. The 100 division on the scale represents an arc equal to a unit segment.

The range finder provides a means of measuring the distortion on received signals. To measure the total net effect of all kinds of systematic distortion, or the position of received signals, the range finder is first moved in one direction until errors appear in the copy, and then moved back slowly until errors are just eliminated. Similarly, the range finder is moved the maximum distance before errors occur in the opposite direction. These two scale readings then give the operating margin of the signals under test. The optimum setting of the receiver for reception of minimum errors is to adjust the indicator arm on the range finder midway between the above scale readings.

3.0 TELEGRAPH SIGNAL MEASURING EQUIPMENT

3.1 Introduction

While electronic station equipment of various types is being introduced for telegraph and low-speed data use, the great bulk of these services will be handled by electromechanical machines for many years to come. Printing telegraph machines of the electromechanical type are intricate mechanisms with a multiplicity of precise mechanical adjustments. The use of electrical test equipment in the field is the only practical method of checking the overall performance of the transmitter and receiver.

The demands for faster and more dependable service with improved accuracy can only be met through the application of high grade maintenance, which requires adequate testing equipment and efficient testing methods. Improvements in these testing devices and methods have been made in the past few years to keep abreast of the rapid advances in the telegraph art.

Unlike telephone transmission, which is concerned with many signal characteristics contributing to transmission quality, telegraph transmission is only concerned with keeping the signal distortion down to the point where the receiving machine is capable of making correct selection and translation of the signal. Therefore, telegraph test equipment is primarily concerned with the nature and magnitude of distortion and its effect on the operation of the receiving machine. Accordingly, telegraph testing equipment is designed to analyze and

measure components of signal distortion, or to produce distorted signals for determining operating margins.

Broadly speaking, the uses fulfilled by telegraph testing equipment fall into three categories:

(a) Service monitoring of actual traffic to verify that standards of transmission quality are being met.

(b) Preventive maintenance, both at time of initial lineup and in subsequent routine tests, to detect tendencies leading to degradation of signal quality before actual trouble develops.

(c) Trouble shooting, i.e., the analysis and localization of trouble conditions.

Test equipment for monitoring service is connected to a working circuit to monitor message signals, and the insertion of the test equipment must not appreciably affect the transmitted signals. The monitoring set is connected like a teletypewriter in the DC loop or local circuit of telegraph terminals or repeaters. It observes teletypewriter signals and registers the presence of unit signal elements, which have been distorted excessively. If the number of these occurrences in a predetermined time exceeds a specified number, an alarm may be sounded, or some other indication given that the service is unsatisfactory or is likely to become so.

Preventive maintenance equipment, used mainly for the initial lineup of telegraph circuits and routine tests, consists of signal generators for sending distortion-free signals, signals with selected degrees of distortion, or both, and distortion measuring devices.

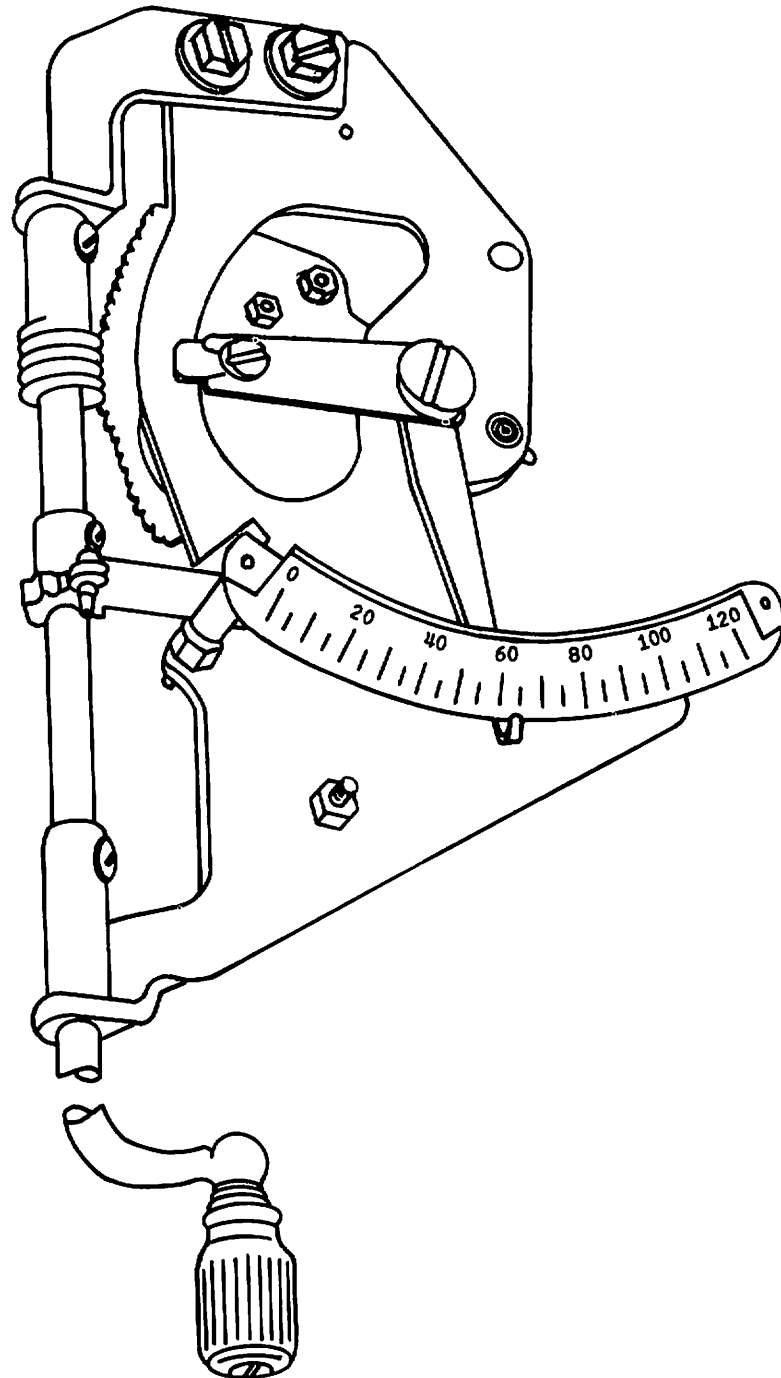
3.2 Sources of Test Signals

3.2.1 Transmitters. An automatic transmitter or a keyboard may serve as a source for test signals, especially when the performance of the transmitting device itself is in question. Monitoring of actual traffic involves signals that are originated by a service transmitter.

3.2.2 Signal Generators. Testing of circuits and receiving devices is generally facilitated if signals are obtained from signal generators that can be adjusted to give signals of nominally zero distortion or various degrees of intentional distortion, and that may furnish any of a number of different types of distortion. In general, the requirement is that the signals generator shall be capable of providing a continuous succession of signals of the desired type so that measurements may be made conveniently. The types of signals desired may include the following:

(a) Simple reversals, i.e., an alternating series of marking and spacing signals. The series may be 1:1 (1.0-unit intervals, alternately) or 2:2 (marking signals 2.0-unit intervals in duration, followed by equal length spacing signals alternately).

(b) Single characters, repeated continuously.



*(From Principles of Electricity as Applied to Telephone and Telegraph.
Used by permission of American Telephone and Telegraph.)*

**TELETYPEWRITER RANGE FINDER MECHANISM
FIGURE E-11**

- (c) Standard test sentences, commonly called fox.
- (d) A sequence of characters, known as Q9S signals (LETTERS, S, CR, LF, Q, FIGS, SPACE, 9), repeatedly.

Signal generators arranged to transmit distorted signals are used extensively in TELEX network offices for marking straightaway transmission tests from subscriber stations.

The transmitter at the central office can be reached by dialing an assigned number. The transmitter sends a test message, e.g., "The quick brown fox jumps over the lazy dog." The code is transmitted sequentially with 20 percent, 30 percent, 36 percent and 40 percent distortion. The degree of distortion is inserted ahead of the test code in undistorted form so that it should always be correctly received. The maximum degree of distortion, which may be introduced into the signals without failure of the receiving apparatus to translate them correctly, is called margin.

3.2.3 Test Signals. In telegraph start-stop test signals, distorted according to American practice, the relative durations of marking and spacing intervals are changed, one at the expense of the other. Therefore, both bias and end distortion, as defined below, are actually forms of bias distortion. For either term, the words marking and spacing are used as modifiers to denote whether the marking or spacing elements are relatively prolonged. The two main types of distortion can be understood with the aid of Figure E-12. Line A shows an undistorted signal for the single character F, in 5-unit code, using a character interval of 7.0-unit intervals. The designations of the signal elements are indicated above line A. The diagram begins at the left end of line A, by showing the end of the preceding rest (stop) element. Next is a unit-interval start element, followed by 5-unit interval information elements. These are followed by the rest element of the character illustrated, having its minimum duration of 1.0-unit interval. The beginning of the following start element is shown. At the top of the diagram, the letters a, b through h represent the ideal instants, or theoretical transition times, with respect to the beginning of the start element. These are spaced 1.0-unit intervals apart.

3.2.3.1 Bias Distortion

Line B of Figure E-12 illustrates marking bias. The M-S (marking-to-spacing) transitions are not changed; they occur at their ideal instants. The S-M transitions are advanced, and the diagram illustrates 25 percent marking bias. The marking elements have a duration of 1.25-unit intervals, and the spacing elements a duration of 0.75-unit interval. The rest element begins 25 percent early also, since it is a S-M transition. Line C illus-

trates spacing bias. The M-S transitions are not changed; however, the S-M transitions are delayed 25 percent of a unit interval, and the beginning of the rest element is delayed 25 percent of a unit interval.

3.2.3.2 End Distortion

Line D illustrates marking end distortion. In end distortion, the ends of the marking elements are changed, i.e., the M-S transitions. The duration of the start element and the S-M transitions is not changed, whereas it is changed in bias distortion. The marking elements are made longer at the expense of the spacing elements so that, at least during the information portion of the character, a 25 percent marking bias condition prevails, according to the general definition of bias distortion. The type of distortion represented by end distortion is seldom, if ever, produced by conditions affecting actual circuits. It is useful for testing, since it displaces the transitions that are not affected by bias distortion and vice versa. Line D shows 25 percent marking-end distortion. Line E illustrates spacing-end distortion in which the M-S transitions are advanced; in this case, 25 percent of a unit interval, so that 25 percent spacing-end distortion is shown. Note that in both kinds of end distortion the durations of the start element and of the rest (stop) element are normal.

3.2.3.3 Early Distortion

Line F on Figure E-12 shows the result of shortening the start element by delaying its start. The subsequent transitions of the character are not affected, but the receiver waits for the beginning of the start element, so that the following transitions all come 25 percent of a unit interval early with respect to the beginning of the start element. Thus, the received signal appears to the receiver as redrawn on line G. The example shows 25 percent early distortion.

3.2.3.4 Late Distortion

Line H shows the result of lengthening the start element by advancing its start by 25 percent. Line I shows the signal as it appears to the receiver; this is 25 percent late distortion.

3.3 Distortion Measuring Sets

3.3.1 General. Many kinds of distortion measuring sets for routine use are commercially available. For the larger offices, rack-mounted equipments are commonly used. Separate metering or indicating devices may be used on a remote control basis in proximity to the telegraph equipment being subjected to test. Repairmen's test equipments used on subscriber premises are lightweight and portable. Some distortion-measuring equipments are electromechanical while others, particularly

those of late design, are wholly electronic. Various principles of measurement of distortion are used, such as stroboscopic methods, direct-reading meters operating from calibrated RC circuits to secure precise timing, cathode-ray tube displays, etc.

Telegraph distortion measuring sets indicate the type and degree of distortion present during the measuring period.

3.3.2 Methods of Connection. The input to a distortion measuring set must be connected to the circuit to be tested in such a way as to minimize the disturbance to the circuit performance. If all circuits to be measured were identical, it would be feasible to use a high-impedance, shunt-type input. The input in this case would be a voltage wave. However, most telegraph devices are current-operated and respond to the current wave rather than the voltage wave. There would be a fixed relationship between the voltage wave and the current wave only if impedance conditions were the same for all circuits, which is usually not the case. This is especially true for circuits operated on a neutral signaling basis where the impedance may be much greater in the open (spacing) condition than in the closed (marking) condition. In polar circuits, the circuit impedance is not changed from marking to spacing, and shunt input is generally acceptable. In neutral circuits, it is necessary to introduce a resistance in series with the circuit to be measured, and to derive the input from the voltage-drop across the resistor. It is desirable to limit the value of this resistor to 100 to 200 ohms in order to hold circuit disturbance to a minimum.

3.3.3 Types of Signals Measured. Practically all of the newer American telegraph distortion measuring sets may be used to measure either start-stop signals or isochronous signals (synchronous system).

Start-stop signals provide a reference point, which is the transition at the beginning of the start element. The measuring circuits derive their reference timing from this transition, and displays are in agreement with this reference instant. Isochronous signals (i.e., equal element signal trains) provide no such repetitive reference point. Instead, a continuous set of reference instants must be established by the measuring set based on timing data obtained with reference to the received signal. In some sets, only the M-S or the S-M transitions are observed, and in others, both M-S and S-M are observed. In any case, automatic adjustments are made, little by little, to bring the derived reference points into coincidence with the average of the transitions observed. Generally, a highly accurate and stable clock is available for use in this process.

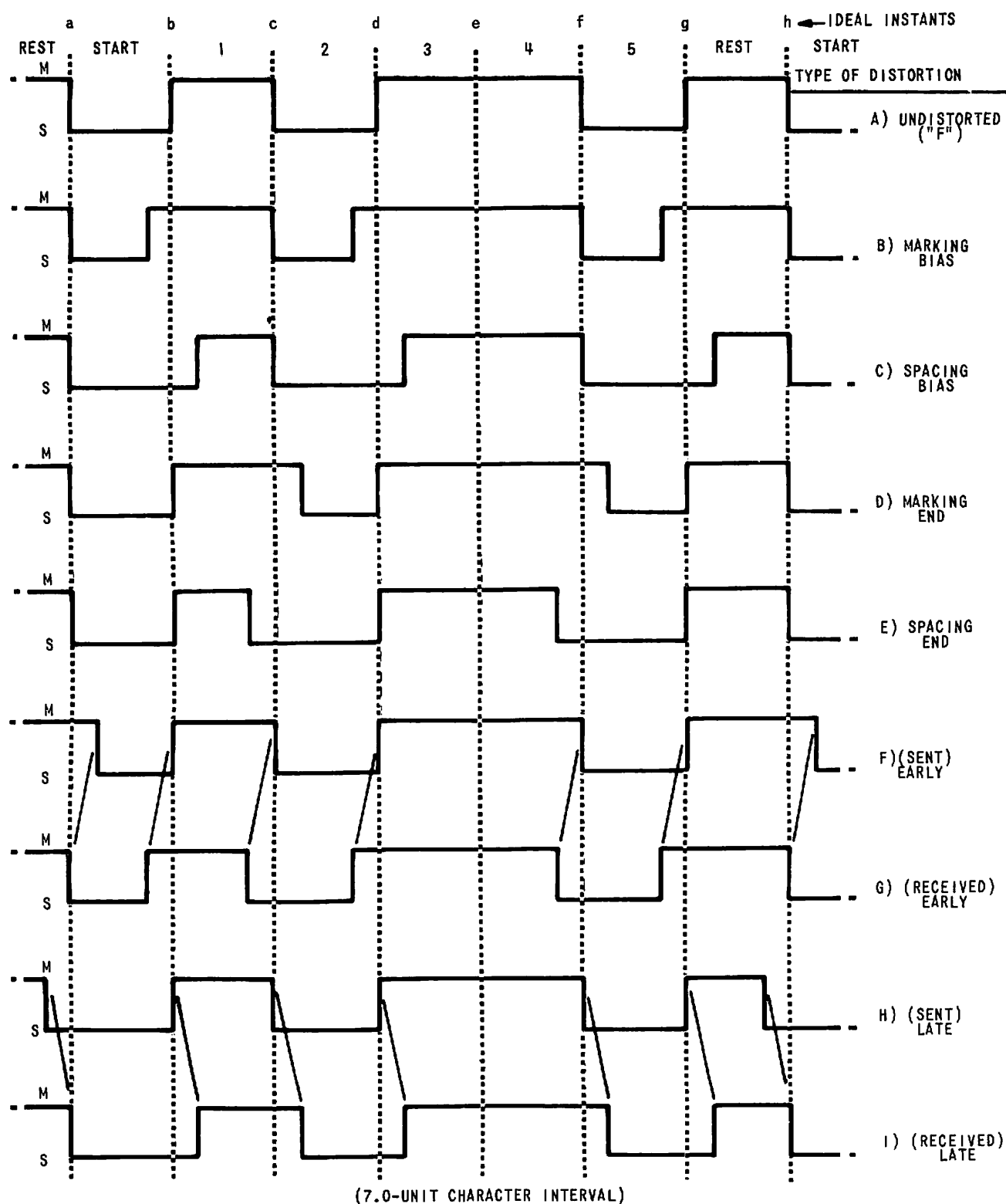
3.3.4 Meter-Reading Distortion Measuring Sets. Perhaps the easiest type of indication for an operator to

read in routine tests is an electrical meter that indicates the distortion figure on a scale. Some of the earliest commercial sets were meter reading types, and modern meter reading sets continue to be selected for certain types of routine measurements, especially in the United States. One example of such an instrument is Teletype-writer Test Set TS-1512/GGM (Figure E-13). It has a panel meter with a large scale reading from 0 to 50 percent distortion, with divisions representing 1 percent distortion. It measures neutral 20 or 60 ma, polar 20 or 30 ma, with series or shunt input, at nominal modulation rates of 37, 45, 50, 61, 74, and 150 bauds. Start-stop characters with character intervals from 7 to 16 can be accepted, and the meter can be made to show the distortion of any single transition, or all of them, in terms of average, early peak, late peak, or total peak, and for mark-space or space-mark transitions. This set also measures isochronous signals. Modulation rates up to 600 bauds can be handled by changing the plug-in circuit cards in the associated time base generator. The latter has a rated stability of one part in 10,000 per day.

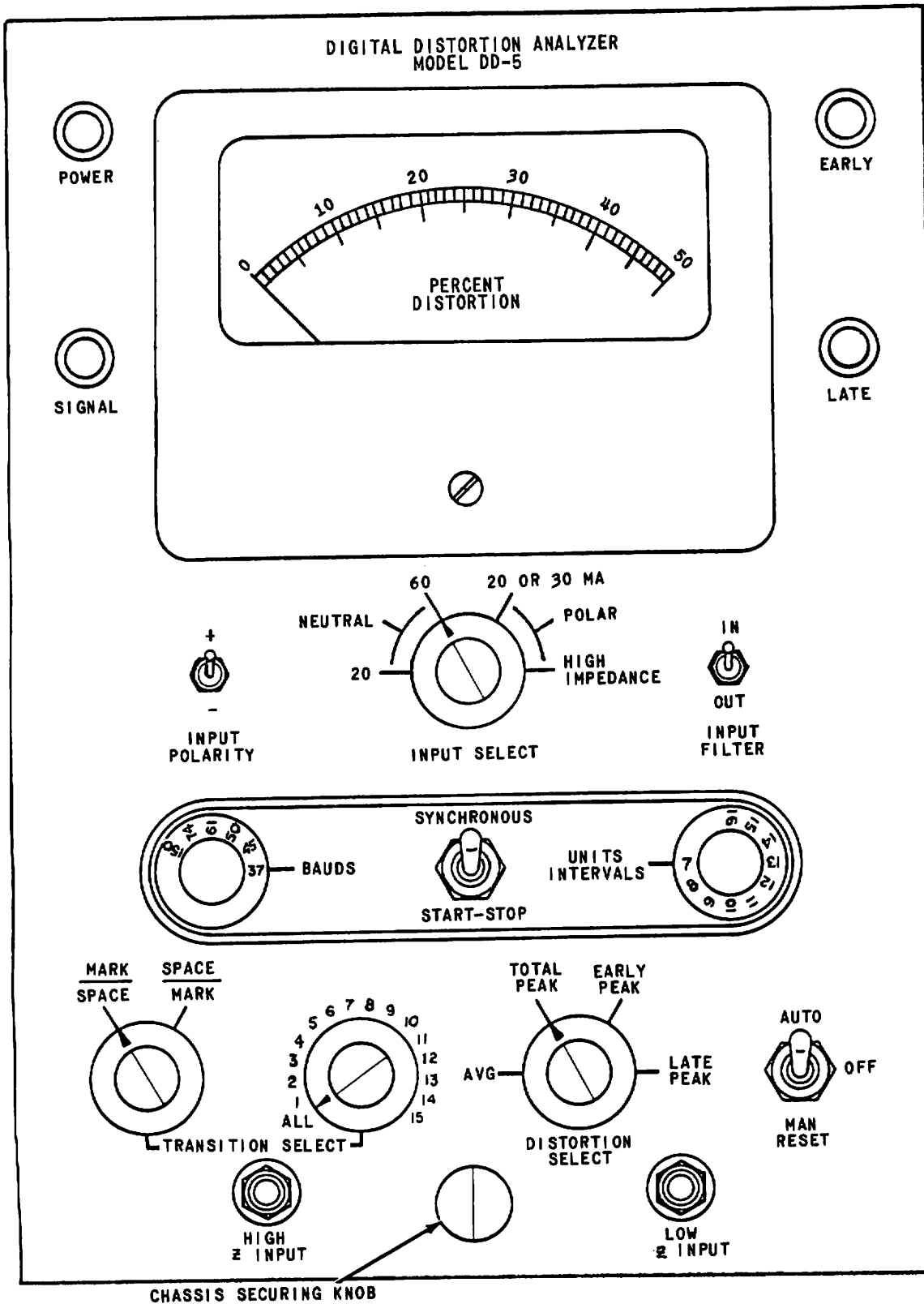
3.3.5 Distortion Measuring Sets with Cathode-Ray Tube Displays. The versatility of the cathode-ray oscillograph has led to the development of a number of distortion measuring sets that indicate signal distortion in various ways. Such sets are generally preferable over meter reading types for analysis and location of causes of signal distortion, since they usually present considerably more information. However, higher skill is required to interpret the data made available. European administrations appear to favor cathode-ray instruments rather than meter reading sets, and some sets of overseas origin are now made under license in the United States. Three different kinds of presentation are available: A-scan, rectangular, and spiral/circular. These will be discussed below.

3.3.5.1 A-Scan Presentation

In A-scan presentation, the signal wave is displayed against a linear, horizontal sweep, as in normal laboratory oscilloscopes. Either the whole character, selected elements, or all elements may be displayed, and distortion can be read-off against a fixed scale. This is probably the type of display that is easiest to understand at a glance, since a signal appears as usually drawn in graphical diagrams (Figure E-12). If distortion is generated in a particular element by some part of the transmitting device, it will at once be obvious which part it is. Jitter or contact bounce is almost readily indentified. Since the trace moves horizontally across a diameter of the tube face, the accuracy is limited unless a very large diameter tube is used, i.e., an element 1-inch long on a 5-inch tube represents 100 percent, and high accuracy cannot be expected from such a display.



TYPES OF TELEGRAPH DISTORTION USED IN TESTING
FIGURE E-12



(Used by permission of Stelma Incorporated, Stamford, Conn.)

TELETYPEWRITER TEST SET, TS-1512/GGM

FIGURE E-13

3.3.5.2 Rectangular Presentation

In what may be called rectangular representation, the trace outlines a horizontal rectangle. Figure E-14 illustrates the presentation of Teletypewriter Test Set TS-1060/GG. Part A illustrates the cathode-ray tube face, with a percent distortion scale from 0-50 below the trace rectangle. The lower trace, part B, is made from left to right; the upper trace returns from right to left. The lower and upper traces each have a 1/2-unit interval duration, so that the rectangle represents a single element of the signal at a time.

When a transition occurs, the ray will jump vertically up for end distortion and down for bias distortion. It will return to the horizontal trace line more slowly, leaving a curved, sloping tail pointing in the direction of motion (part C). If there is no distortion, both upward and downward pips will appear at the extreme left end of the lower trace, adjacent to the letter M in part A.

In part A, numbered pips representing three different distorted transitions have been drawn together for illustration. Pip 1 is downward, representing bias distortion, and it is on the upper trace marked M (marking-bias distortion). The pip is above 35 on the scale, so that the complete indication for pip 1 is 35-percent, marking-bias distortion. Similarly, pip 2 shows 20-percent, spacing-end distortion, and pip 3 indicates about 13-percent, marking-end distortion. If all of these pips appeared simultaneously, the peak reading would be that of pip 1 (or 35 percent). Signals from a line with fortuitous and characteristic distortion will produce both upward and downward pips, depending on whether the distorted transitions are M-S (up) or S-M (down). The same type of indication is given for either start-stop or isochronous (synchronous) signals.

3.3.5.3 Spiral/Circular Presentation

A technique employed in the routine measurement of distortion on start-stop telegraph signals is the use of a transmission distortion measuring set (TDMS). (See Figure E-15.)

In the spiral/circular presentation, a circular time base is used. Around the circumference of a 3-inch cathode-ray tube is a scale that reads from zero at "12 o'clock" both clockwise and counterclockwise to 50 percent at "6 o'clock." For start-stop signals, the trace is a spiral of constantly diminishing radius, one revolution per single element, thus providing a separate indication for each element. Transitions are indicated by a brightening of the trace, which makes a spot. In Figure E-15, part A, which shows the indication for undistorted signals, the bright spots are in a vertical row at zero percent.

In Figure E-15, part B, a signal with 20-percent, marking-bias distortion is indicated. Note that the outside spiral trace, which corresponds to the start element, has a spot at 20 percent. This indicates that the S-M transition that ends the start element has occurred 20 percent of a unit interval before its ideal instant. This corresponds to the distortion shown in Figure E-12, line B, transition b, which also shows marking bias (25 percent in this case).

The indication for a case of fortuitous distortion is shown in Figure E-15, part E. Two spots representing distorted transitions are shown, one early (left) and one late (right). They are both included in an angle representing 5 percent early and late distortion, hence the reading is ± 5 -percent fortuitous distortion.

When measuring isochronous (synchronous) signals, the trace is changed to a circle (not shown). Since the circular scale of a 3-inch tube is over nine inches in circumference, it permits a relatively high degree of accuracy. An operator could probably estimate to about 1 percent on such a scale.

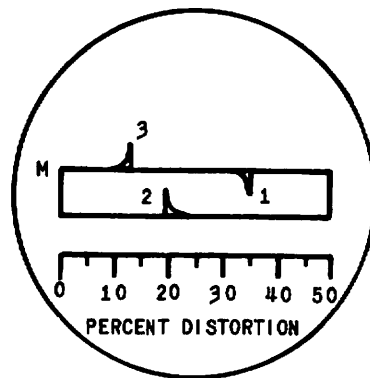
3.4 Telegraph Distortion Analyzer

3.4.1 Discussion. A telegraph distortion analyzer provides a means of establishing an interrelationship between signal distortion, receive margin of terminal apparatus, and error rate in reception, as well as providing supporting data needed to plan extensive teletypewriter networks.

A distortion analyzer proves useful in investigating the relative importance of the various components that make up total distortion. The condition of signals delivered by transmitting keyboards, or regenerative repeaters, can be determined by such measurements, as well as by tests to check the operation of receiving printers. The analyzer provides a convenient means for analyzing trouble conditions and determining their causes.

3.4.2 Measurement. Where the standard of service on a particular circuit or connection is to be assessed, one should know the probability of any particular value of distortion occurring or, on the complete connection, the probability of some limiting value of distortion being exceeded.

Telegraph distortion measuring sets, as discussed in previous paragraphs, are used to indicate an average value of distortion present during the measuring period. However, the average value of distortion gives only a limited amount of information about the channel being tested.



A) DISTORTION INDICATIONS

- 1 - 35% MARKING BIAS DISTORTION (PEAK)
- 2 - 20% SPACING END DISTORTION
- 3 - 13% MARKING END DISTORTION

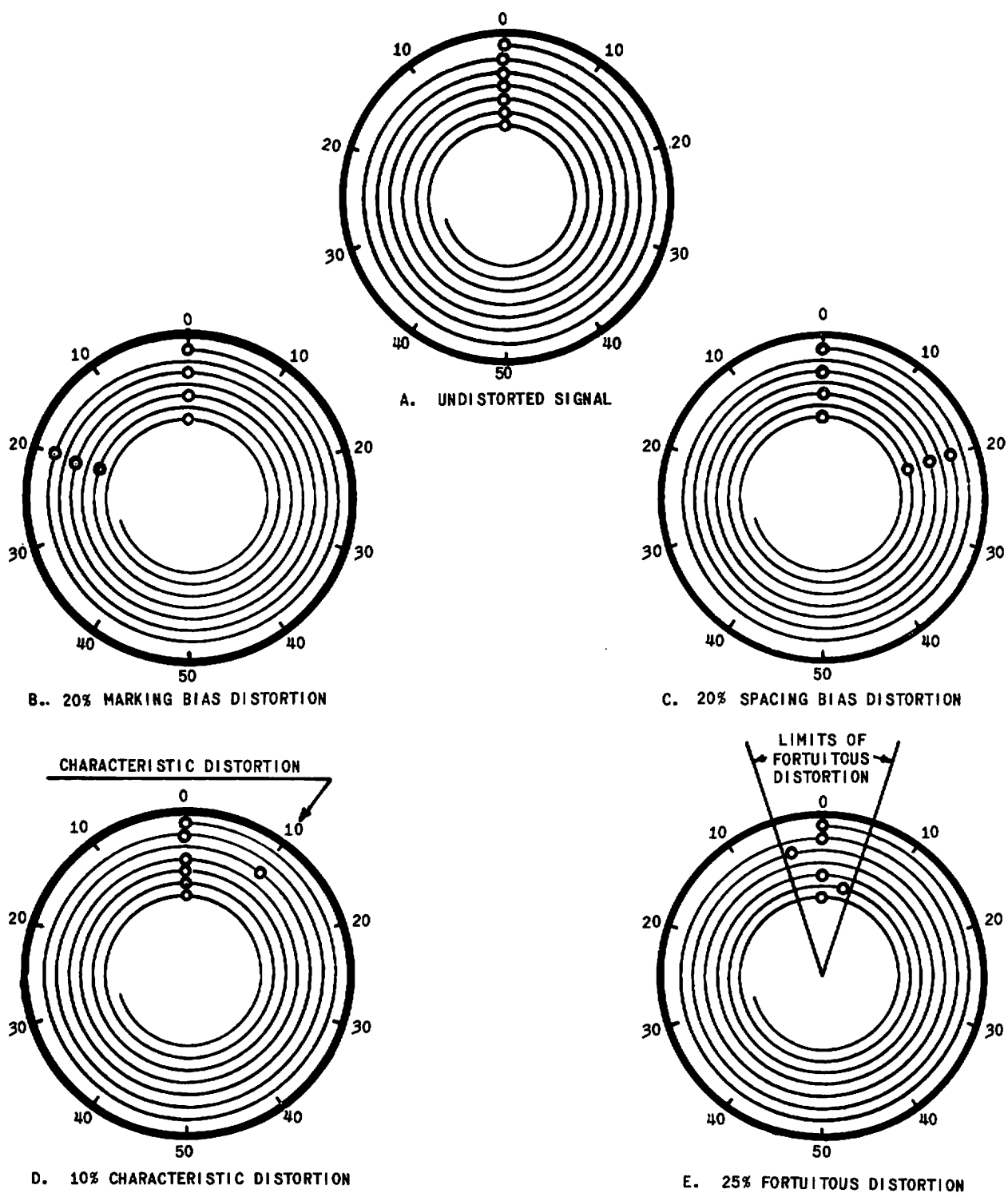


B) DIRECTION OF TRACE



C) SENSE OF PIPS

**DISTORTION INDICATIONS ON TELEGRAPH DISTORTION MEASURING SET
WITH RECTANGULAR DISPLAY
FIGURE E-14**



TYPES OF DISTORTION AS SEEN ON A TDMS WITH SPIRAL DISPLAY
FIGURE E-15

It is quite common for two circuits which have the same average distortion to perform very differently. A telegraph distortion analyzer, on the other hand, provides information allowing the differences to be assessed quantitatively, and the design of the network to be soundly evaluated. Such information is provided by sampling a number of pulse transitions (or characters), measuring the displacement (or distortion) of each, and recording the number of times that the distortion falls within a predetermined value.

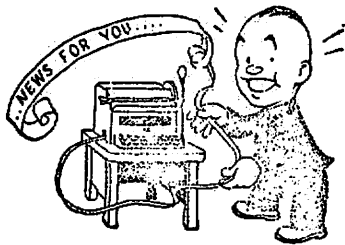
A distortion analyzer has been developed that includes 40 counters, which may be used to indicate the frequency of occurrence of distortion in steps of 2.5 percent over the entire range of ± 50 percent, or in increments of 1 percent over a range of ± 20 percent distortion. In the latter case, another counter reveals how often a distortion exceeding 20 percent was present in the line.

A somewhat different approach to the problem of signal analysis is a visual indication used to display

various degrees of distortion, including signals arising from defective telegraph apparatus. A recording disc or chart, divided into sections corresponding to a particular unit code, is rotated through one complete revolution whenever a printed character is received. Each pulse transition of the measured signal causes a mark to be made on the paper. The departure of these marks from the ideal radial lines printed on the chart is then a measure of the distortion. As the recording stylus is directed towards the center of the disc, each revolution of the disc corresponds to a different character.

In the case of bias distortion (recorded) pulse transitions are shifted systematically in either direction (marking or spacing bias) with respect to the ideal points. Fortuitous distortion, on the other hand, causes the signal transitions to be shifted about in a random fashion. Defective commutator segments, faulty communication transmitter contacts, transmission speed variations, and other similar discrepancies are also detectable when using such a method.

PART F
TELETYPEWRITERS AND
ASSOCIATED EQUIPMENT



Part F

Teletypewriters and Associated Equipment

1.0 TELETYPEWRITER CHARACTERISTICS

1.1 Description

1.1.1 *General.* The information contained in this chapter is confined to the page-printing type of teletypewriter.

Teletypewriters are motor-driven machines that provide the mechanical means to interchange typewritten messages transmitted electrically by wire, carrier, or radio between two or more points. They may be started and stopped by any station connected in a circuit. The equipment used at fixed stations is usually more extensive than equipment used at field (mobile) stations, but the operating principles are identical. In both cases, a keyboard transmitter (or other device, such as a transmitter distributor) is required to send a message; a wire or radio channel is required for transmission; and a teletypewriter (or similar mechanism, such as a reperforator) is required to receive and record the message. Although teletypewriter transmission and reception are electrical, current teletypewriter equipment is largely mechanical; however, the trend in research and development is toward electronics. Cams on a revolving shaft in the keyboard transmitter at the sending station cause the signal code for the depressed key to be impressed on the line or transmission channel, and cams on a revolving shaft in the receiving teletypewriter cause the pulses to be received, stored, translated, and recorded. The basic units of a send-receive teletypewriter set include a keyboard unit, a page printer, a motor unit, and a cabinet. The cabinet supports the other three units. A typical teletypewriter set and basic units are shown in Figures F-1, F-2, F-3, F-4A, and F-4B.

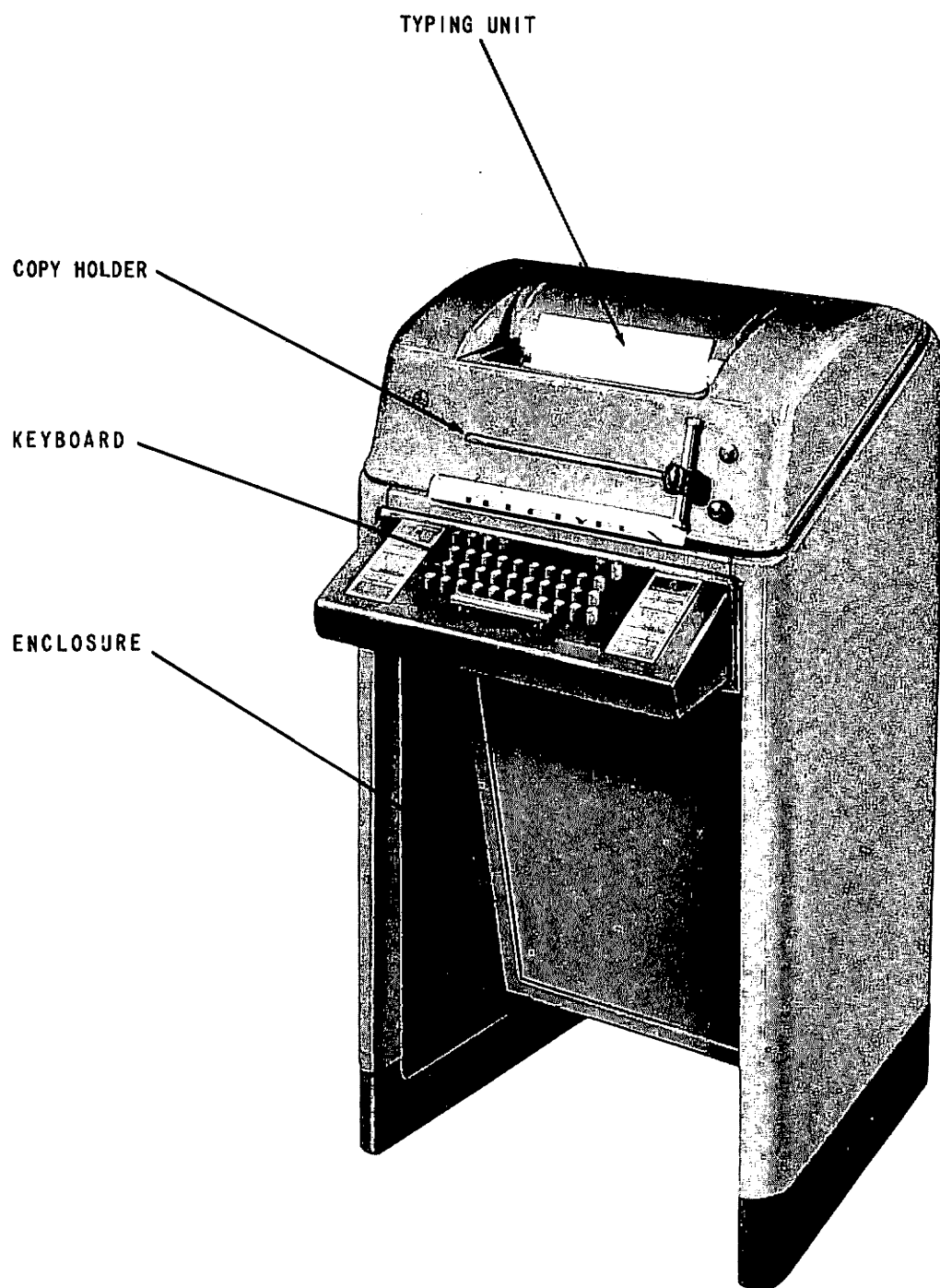
1.1.2 *Specification (General).* An assembled teletypewriter set occupies a space approximately 20 in. deep (front to rear) x 21 in. wide x 40 in. high. It weighs about 120 lbs. (Some of the more recently developed teletypewriters are considerably smaller and lighter.) Teletypewriter operating speeds are in the order of:

368 Operations per Minute (60 words per minute)
404 OPM (67 wpm or 50 baud)
460 OPM (75 wpm)
600 OPM (100 wpm) as desired

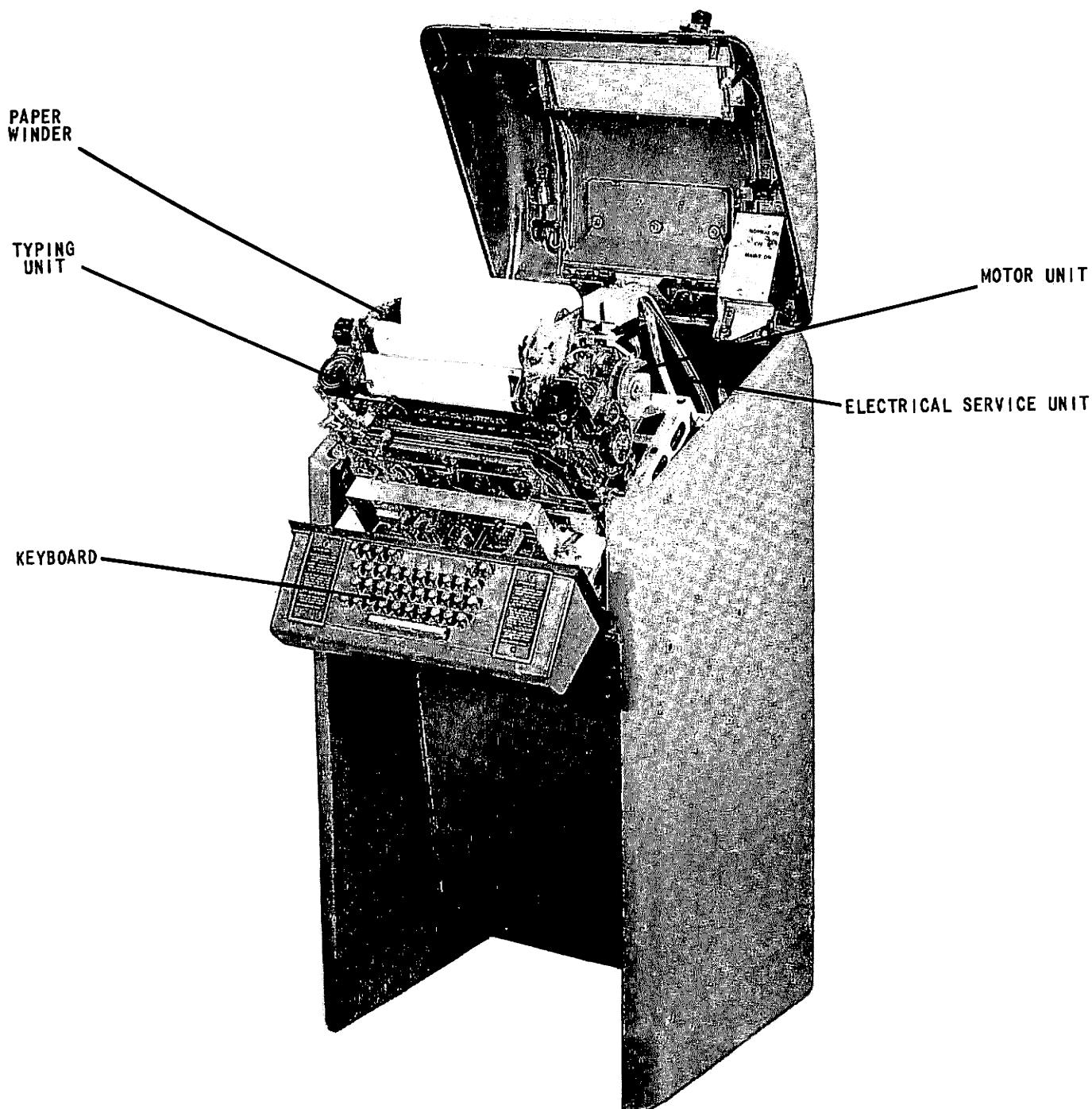
Sets of gears for the various speeds are supplied as optional components. The signals received by the Model 28 Printer are of the start-stop type. The equipment is wired at the factory to transmit neutral signals but is readily adaptable to transmit polar signals by wiring changes.

1.1.3 *Power Requirements.* The power normally required to operate a page-type teletypewriter and to furnish the line current is about 200 watts. The governed series-wound motor operates with 110- to 120-volt, 50- to 60-cycle AC or DC power. The required DC line current is approximately 60 ma, and is usually furnished from one end of the line only. When a station is only required to operate a teletypewriter, and regulated 60-cycle AC is available, a synchronous (one speed) motor unit may be used, and the station may be operated without a local power source. However, this arrangement seldom is used by the Armed Forces except in large communication centers. Usually, where commercial power is available, a rectifier is used as a source; where commercial power is not available, as in tactical installations, a motor-driven power unit is used. In addition to furnishing the DC required, both the rectifier and the motor-driven power unit are arranged to furnish current to operate the teletypewriter motor unit. A rectifier or power unit as a teletypewriter station permits the use of auxiliary equipment (a line relay or a line unit) to facilitate operation over greater distances and less desirable circuits, and to improve performance and flexibility.

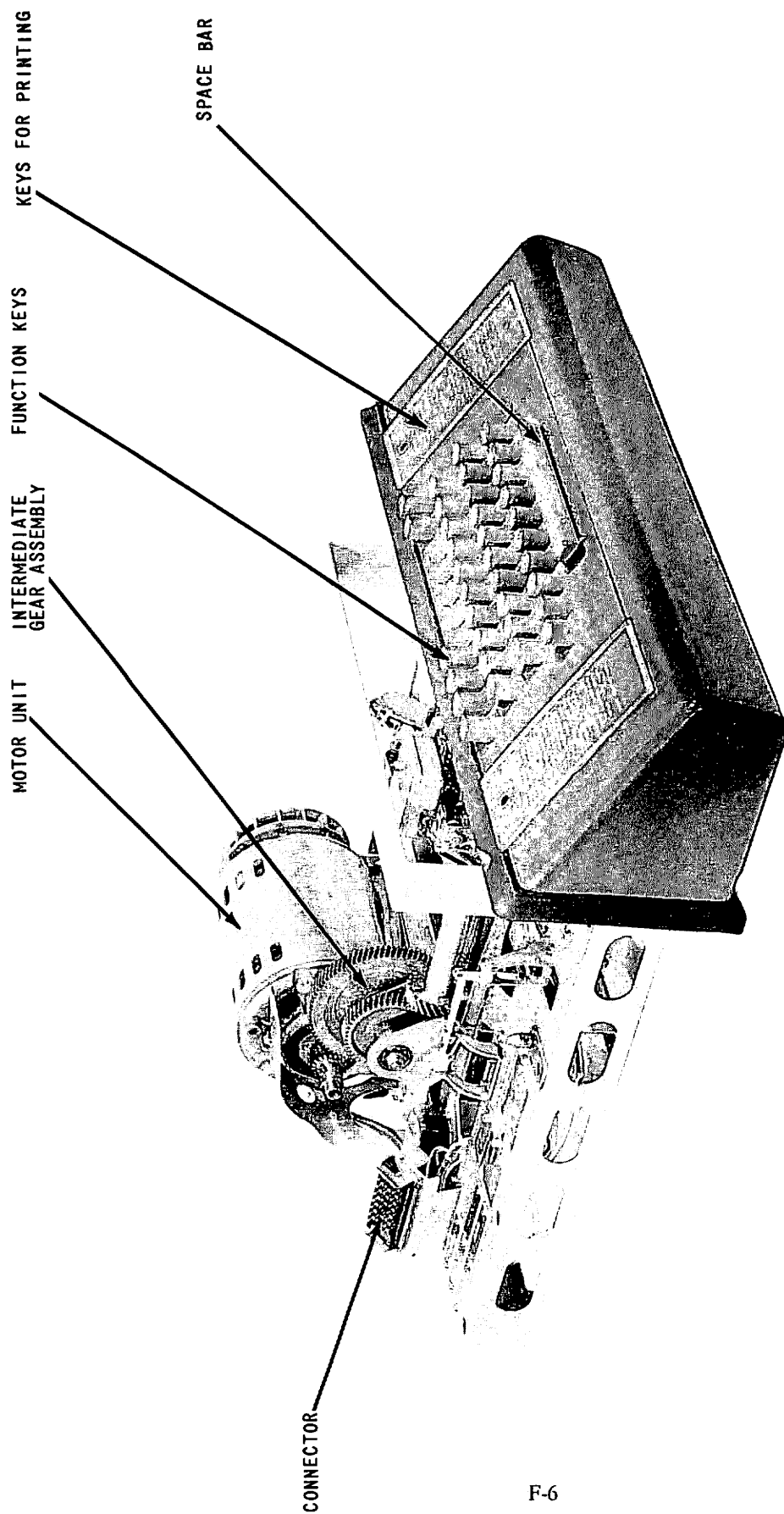
1.1.4 *Control.* Teletypewriters connected in the same circuit may be started by any station through the use of a mechanical motor control by momentarily opening the signal line. They may be stopped by any station by first depressing the figures key (FIGS), and then the upper case H key.



(Photograph courtesy of Teletype Corporation.)
TELETYPEWRITER SET MODEL 28
FIGURE F-1

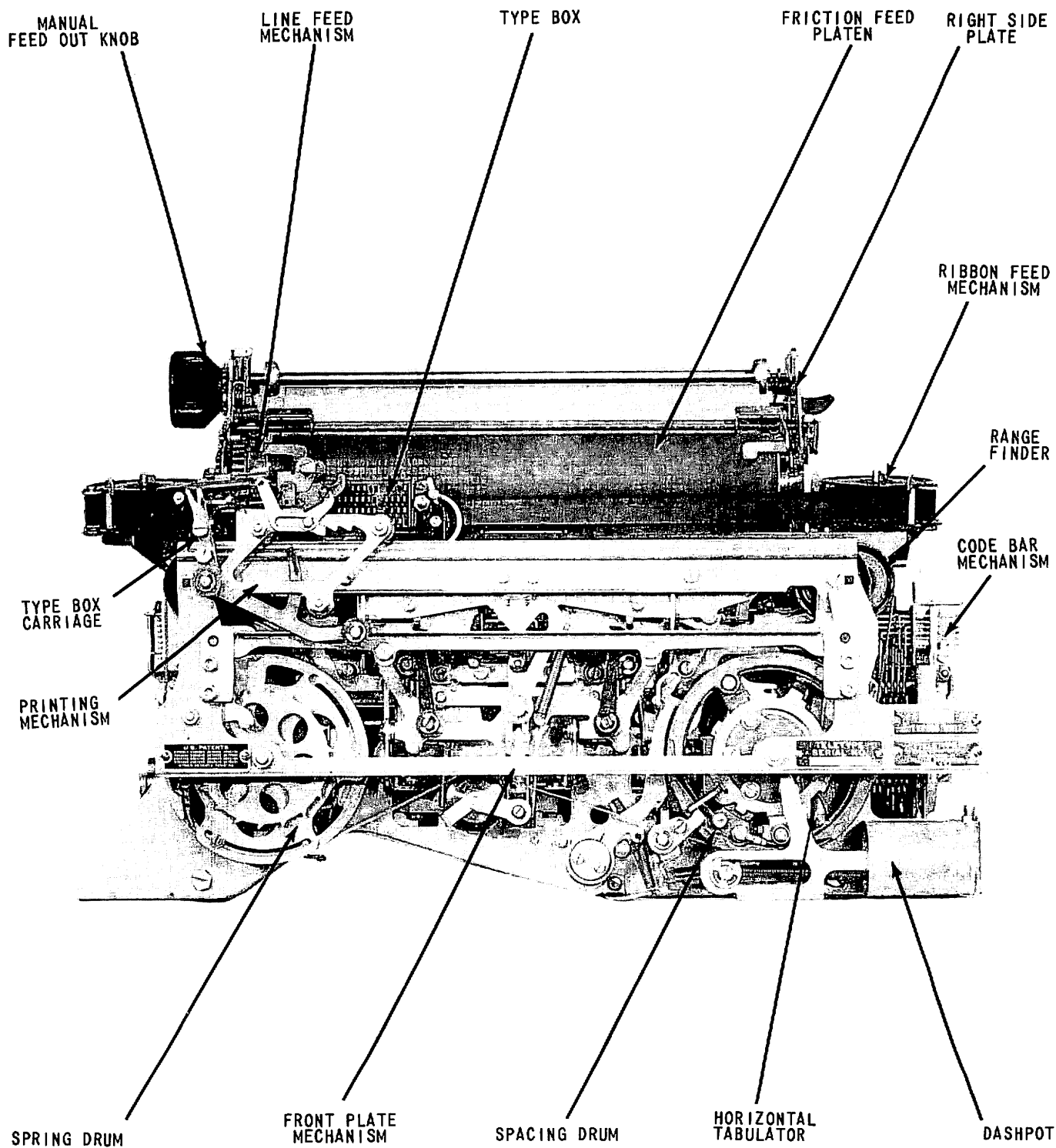


(Photograph courtesy of Teletype Corporation.)
TELETYPEWRITER SET, INTERIOR VIEW (MODEL 28)
FIGURE F-2

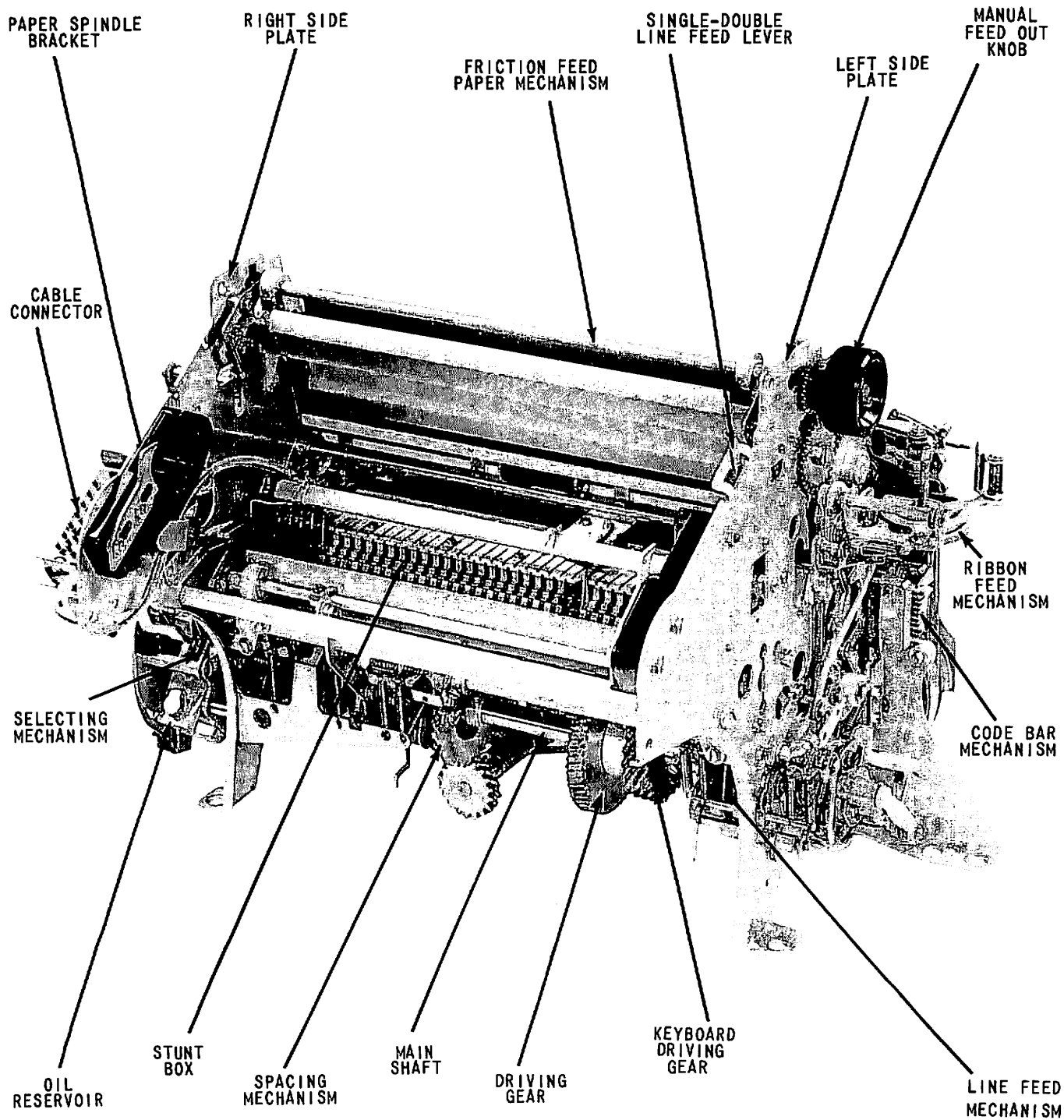


F-6

(Photograph courtesy of Teletype Corporation.)
TELETYPEWRITER KEYBOARD, MODEL 28
FIGURE F-3



(Photograph courtesy of Teletype Corporation.)
TELETYPEWRITER TYPING UNIT, FRONT VIEW (MODEL 28)
FIGURE F-4A



TELETYPEWRITER TYPING UNIT, REAR VIEW (MODEL 28)
FIGURE F-4B

1.1.5 Operating Features. Send-receive teletypewriter sets usually have friction paper feed, series-governed or synchronous motors, a remote control motor stop (operated by the upper case H key), and a rectifier (for local or line current) with built-in transformers for a 95- to 125-volt and 190- to 250-volt, 25- to 60-cycle input. The transformer of the rectifier unit includes variable tap windings for adjusting motor terminal and DC voltages. Signaling is accomplished through the use of the 5-unit code of marking and spacing electrical impulses produced by mechanical action of a transmitting unit. These impulses are reconverted to mechanical action by the selector mechanism of a typing unit.

1.1.6 Utilization. In cases where a line is short and no appreciable variation in line conditions exists, it is possible to establish communication between two teletypewriters by interconnecting them directly over a pair of wires (or one wire and ground return) if the correct DC voltage is furnished in series with a current-limiting resistance. In the majority of cases, however, some equipment in addition to the teletypewriters and power source is necessary to maintain and control the line or loop. Such equipment may include a current-limiting resistance installed in the teletypewriter or its table, and external equipment, such as line units, DC repeaters, telegraph switchboards, telegraph carrier terminals, and speech-plus-duplex terminals.

1.2 Breakdown of Teletypewriter Components

1.2.1 The Cabinet. The cabinet is of sheet metal construction and approximately 40 in. high x 20½ in. wide x 18½ in. deep. The upper portion forms a compartment for housing the mechanical units and electrical service unit. A shelf in the lower section may be used to mount a rectifier unit. Terminal boards for power and signal line connections are located on the inner rear wall.

1.2.2 Keyboard Transmitter. The keyboard transmitter (Figure F-3) includes all of the mechanism required to form and transmit 5-unit code teletypewriter signals for letters, symbols, or nonprinting functions. There are two keyboard arrangements in general use in the military forces; *standard communications* (Figure F-5) and *weather reporting* (Figure F-6). The keyboard transmitter consists of a set of keys, keylevers, a universal bar, selector bar, slip connections for connecting it electrically to the base, and a transmitting unit with a transmitting contact filter, all mounted on a cast-iron frame. In general appearance, the teletypewriter keyboard resembles a typewriter keyboard. However, there are a number of differences. The more important ones are as follows:

(a) The capacity of the teletypewriter keyboard is limited by the use of the 5-unit code to 32 keys including the space bar. A typewriter keyboard has a minimum of 45 keys.

(b) Four of the teletypewriter keys are required to perform, electrically, functions that are performed manually on a typewriter. These functions are CARRIAGE RETURN, LINE FEED, FIGS (shift), and LTRS (unshift). One key is used for the blank function which is not used with a typewriter, and the remaining 26 keys are required for the letter codes.

(c) On a teletypewriter only capital letters are used.

(d) Figure symbols are the third "highest" row of keys. Punctuation or special symbols are located on the first and second rows.

(e) The teletypewriter is shifted from letters to figures, punctuation marks, or special symbols by means of the FIGS shift key.

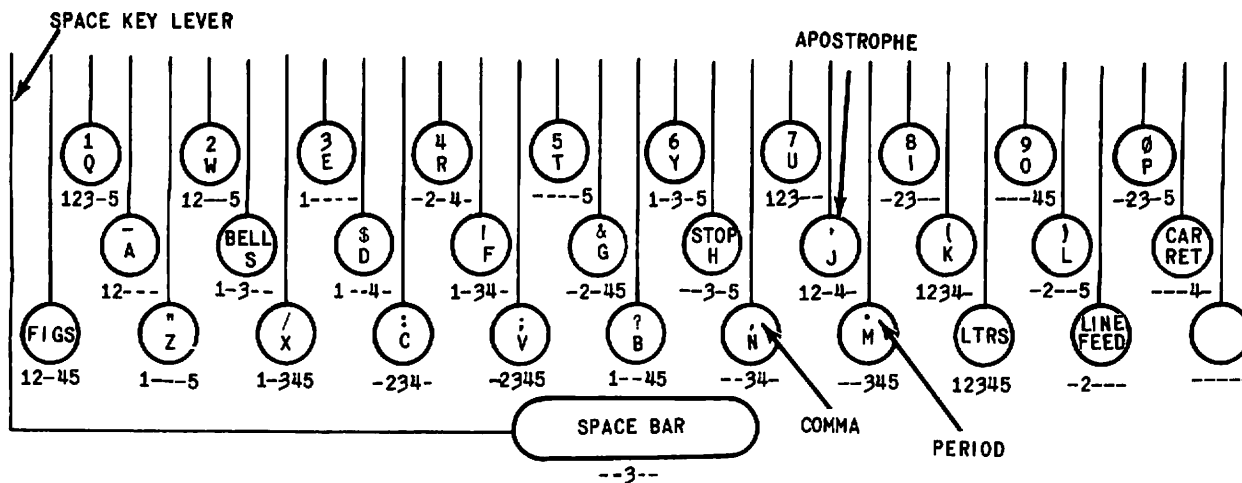
(f) The machine is returned to the letter position by means of the LTRS shift key.

1.2.3 Motor Unit. The motor units are self-contained components that mount on the rear of the keyboard base and have characteristics adaptable to standard power supplies. Mechanical power for operating the typing unit and keyboard unit is provided by gearing the motor to the main shaft, which in turn is geared to the keyboard transmitter shaft.

The motor units may be governed, series-wound motors, or AC synchronous type. The synchronous type is preferable when power line frequency has a close regulation.

1.2.4 Typing Unit (Page Printer). The typing unit (Figures F-4A and F-4B) includes in a single assembly all the mechanism (except the motor) required to receive 5-unit teletypewriter code signals, and to convert them into typewritten messages. It may be used at receiving-only stations without a keyboard transmitter. All mechanically operated parts of the typing unit receive their motive force from the main shaft assembly. This assembly is connected directly through the main shaft gear to the motor pinion. When the motor revolves, it transfers power through the various cams, gears, and clutches to move the various parts of the typing unit. These parts move at a speed required to synchronize their mechanical actions with the code impulses that electrically energize the selector magnet. The selector magnet, through the associated selecting mechanism, determines the operation of the typing unit in printing a symbol or performing a nonprinting function of the equipment.

In some machines a function box or "Stunt Box" is located at the rear of the typing unit to perform



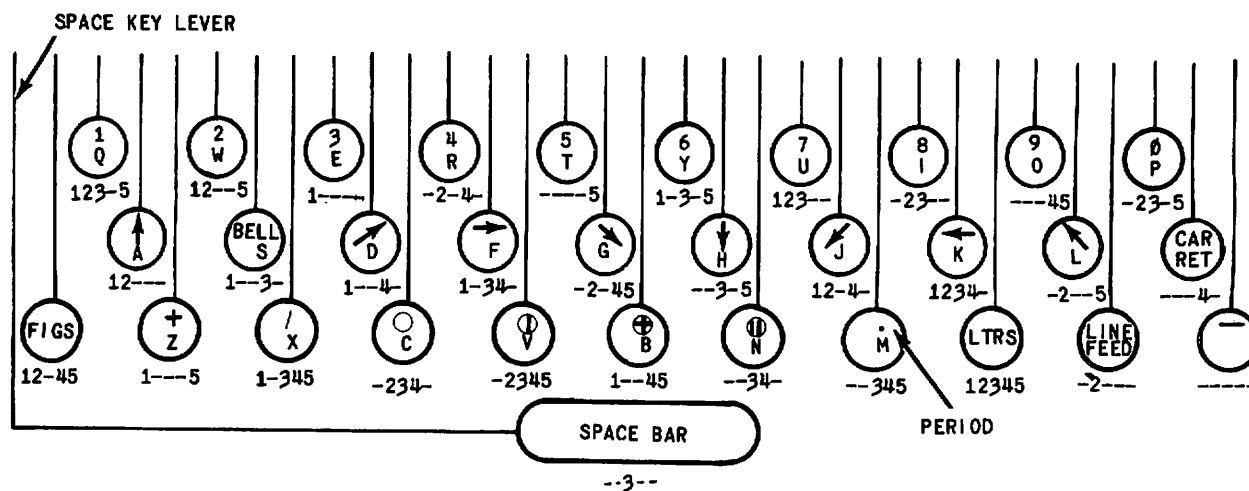
NOTE:

NUMERALS SIGNIFY MARKING CODE IMPULSES.

DASHES SIGNIFY SPACING CODE IMPULSES.

KEYBOARD ARRANGEMENT JX USING 103652 SET OF MASTER SPEED KEYTOPS, WITH ASSOCIATED CODE, FOR STANDARD COMMUNICATIONS PRINTER.

STANDARD COMMUNICATIONS KEYBOARD AND ASSOCIATED 5-UNIT CODE FOR EACH CHARACTER
FIGURE F-5



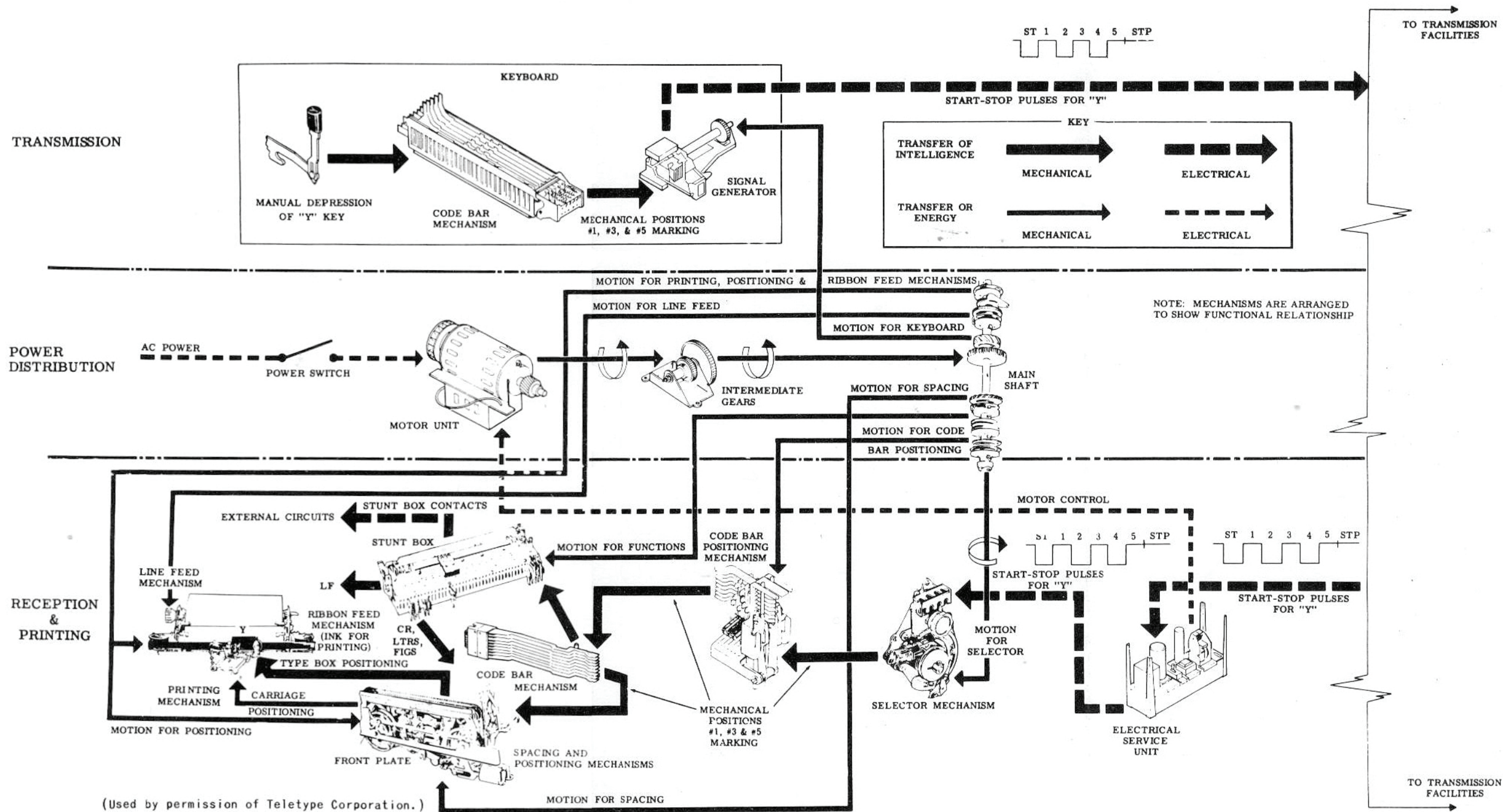
NOTE:

NUMERALS SIGNIFY MARKING CODE IMPULSES.

DASHES SIGNIFY SPACING CODE IMPULSES.

KEYBOARD ARRANGEMENT KQ USING 105278 SET OF MASTER SPEED KEYTOPS, WITH ASSOCIATED CODE, FOR WEATHER REPORTING PRINTER.

WEATHER COMMUNICATIONS KEYBOARD AND ASSOCIATED 5-UNIT CODE FOR EACH CHARACTER
FIGURE F-6



TELETYPEWRITER FUNCTIONAL DIAGRAM—MODEL 28
FIGURE F-7

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functions (nonprinting operations). Extending across the full width of the typing unit, it has 42 code spaces. Ten are reserved for the common functions: line feed, local carriage return, etc. The remainder of the Stunt Box can become a built-in sequential selector to initiate mechanical motions within the machine or remote operations by means of electrical switches.

1.2.5 Functional Diagram. The relationship of the operating components of the teletypewriter are illustrated in the functional diagram, Figure F-7.

1.3 General Operational Theory of Teletypewriter (Start/Stop)

1.3.1 General. A sending teletypewriter set must convert the mechanical action of the keylevers on the keyboard into electrical pulses, and a receiving teletypewriter set must receive the electrical pulses and convert them into mechanical action to print a letter, a numeral, or a symbol, or perform a nonprinting function.

The overall speed of all teletypewriters in a circuit must be approximately the same. However, some slight difference in speed between machines in a circuit exists in all cases. These differences are due to variations in the action of friction clutches, friction in the bearings, viscosity of the lubricants, and other factors. Teletypewriter communication requires that differences in operating speeds must be kept within certain limits. They also must be prevented from being accumulative.

Maintenance of correct timing between transmitting units and receiving units in a circuit is achieved by means of the start-stop system of operation. With this system, the transmitting and selector mechanisms are driven by friction clutches whose driven members are stopped after each code group is transmitted, and started again at the beginning of transmission of the next code group. This insures that all machines will be in exact synchronism at the beginning of transmission of each code group and prevents any difference in operating speed for being accumulative, resulting in errors. Thus the transmitting and receiving equipments connected in a circuit will come to a stop at some point between the completion of transmission of one code group and the beginning of the next. With the next start (spacing) pulse, these equipments will start their sequences together, and if the motor speeds are correct, they will complete their sequences without losing their synchronism.

The details of electromechanical operation of a representative low-speed teletypewriter set (Model 15-Teletype Corp.) are described in the following paragraphs.

1.3.2 Teletypewriter Sending Mechanism. The teletypewriter sending unit now in general use consists principally of a keyboard with keylevers extending over

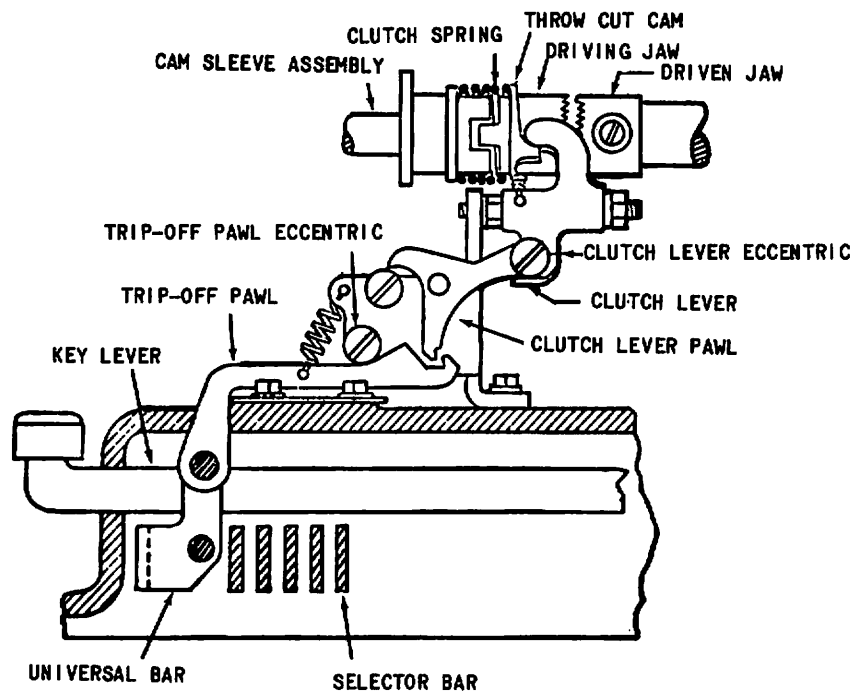
five notched selector bars, and a start-stop mechanism of driving and driven shaft, universal bar, cams, eccentrics, levers, and pawls. Figure F-8 shows the general mechanical arrangement of the start-stop mechanism.

Figure F-9 shows the details of the keylever, which, when pressed down, positions the selector bar. The selector bar, in turn, moves the locking latch head forward or back. This latch will either prevent the contact lever from closing the transmitter contacts (latch head forward) or permit the contact lever to close the contacts (latch head back), when the associated selector cam depression arrives at the proper projection on the contact lever. Thus, as a key lever is depressed to send a particular character, the universal bar is moved down, causing the mechanism (Figure F-8) to function and the selector cam to start rotating. At the same time, the five selector bars and locking latches are positioned by the keylever, and each of the five contact levers is either locked or left unlocked, so that, as the selector cams make one revolution, each set of transmitter contacts either remain open or closed. If the contacts remain open, a spacing signal (no current) is sent over the line. If the contacts close, a marking signal (current) is sent over the line.

Release of the key lever after it has been fully depressed causes the driven jaw to be thrown out of engagement with the driving jaw upon the completion of one revolution of the cams, and the rotating movement stops. The mechanism is now ready to send the next character.

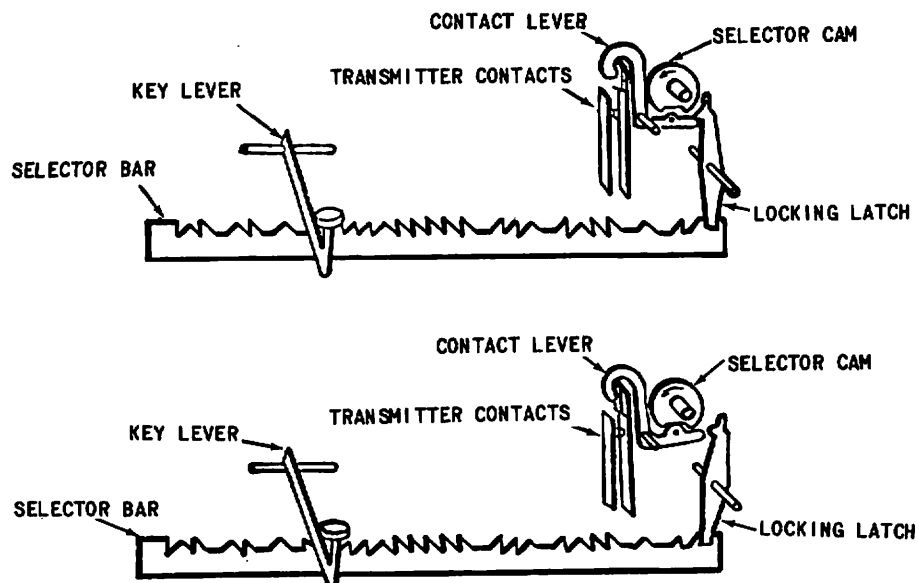
1.3.3 Teletypewriter Receiving Mechanism. The teletypewriter receiving mechanism generally employs a single selector magnet working with a group of six rotating cams, so spaced angularly on a shaft that each cam functions at the instant the corresponding signal pulse is being received.

Figure F-10 shows the mechanical arrangement for translating the selector magnet operations into the positioning of the code bars. When the open pulse is received, the magnet armature releases. This operates a latch (not shown) allowing the cam shaft to rotate. The spacing of the cams on the shaft is such that, as the first of the five pulses of the code signal is being received, the first cam engages the projection of the code-bar-operating-lever associated with the first code bar and rotates it slightly in a counterclockwise direction. Assuming that the received No. 1 pulse is marking, the armature will be operated, and the movement of the code-bar-operating-lever will lift the sword and cause its upper right-hand projection to strike the right-hand end of the armature extension. The sword will then rotate in a clockwise direction on its pivot. When the selector cam clears the code-bar-operating-lever and



(From *Electrical Engineer's Handbook* by Pender and McIlwain, New York, 1950.
Used by permission of John Wiley & Sons.)

START-STOP MECHANISM OF TELETYPEWRITER SENDING UNIT
FIGURE F-8



(From *Electrical Engineer's Handbook* by Pender and McIlwain, New York, 1950.
Used by permission of John Wiley & Sons.)

POSITIONING OF TRANSMITTER CONTACTS BY OPERATING KEY LEVER OF
TELETYPEWRITER SENDING UNIT
FIGURE F-9

allows the latter's spring to return the lever to normal, the sword point will be forced against the left-hand projection of the T lever, rotating it in a counterclockwise direction and moving the No. 1 code bar to the right. If the received No. 1 pulse had been spacing, this code bar would have been moved to the left.

In like manner, the other four code bars are properly positioned and the sixth cam releases a clutch, allowing the printing mechanism to operate, as shown in Figure F-11. The five code bars have been positioned to the right or left in accordance with the five code pulses received, representing a particular character. The code bar slots will then line up so that the pull bar for that character will center in these, and only these, slots, and will engage the main bail. This bail is then moved forward, causing the pull bar to move forward and the type bar head to be driven against the paper or tape in the teletypewriter.

After completion of one revolution of the rotating cams, the rotating movement stops, owing to action of the stopping mechanism, and the teletypewriter is then ready to receive the pulses for the next character.

2.0 ASSOCIATED EQUIPMENTS

2.1 General

In direct teletypewriter keyboard transmission, the sending of code pulses over the signal line is manually controlled. The operator strikes a key, electrical code pulses travel over a signal line, and the character is typed at one or more distance teletypewriters.

Another method of dispatching code pulses over a signal line is by automatic transmission. Here keyboarding and sending are separated so that each can be controlled individually. The keyboarding is done by a tape perforator, which punches holes corresponding to the signal code in a paper tape. The coded tape is then fed into a transmitter distributor (a combination of paper tape reader and multiple wire distributor). This unit senses the code holes in the tape, and makes electrical contacts, which automatically send the pulses over the line via the distributor. At the receiving end, the code signals can be either translated into page copy or punched tape, depending on the receiving apparatus employed. For page copy, the receiving machine is a teletypewriter, and for punched tape, the receiving machine is a tape reperforator. Punched tape introduces speed and flexibility into a system, which is not always possible with direct keyboard transmission.

2.2 Tape Perforator (Tape Punch)

(a) The 5-unit tape perforator or tape punch (Figure F-12) is used to prepare perforated tape for

automatic transmission of teletypewriter signals. When perforated tape is fed automatically through a transmitting device (transmitter distributor), it will operate teletypewriter equipment at one or more stations connected in the same circuit. The combination of holes in the tape, corresponding to the pulse code, determines the characters to be printed on teletypewriter receiving equipment, or the functions to be performed.

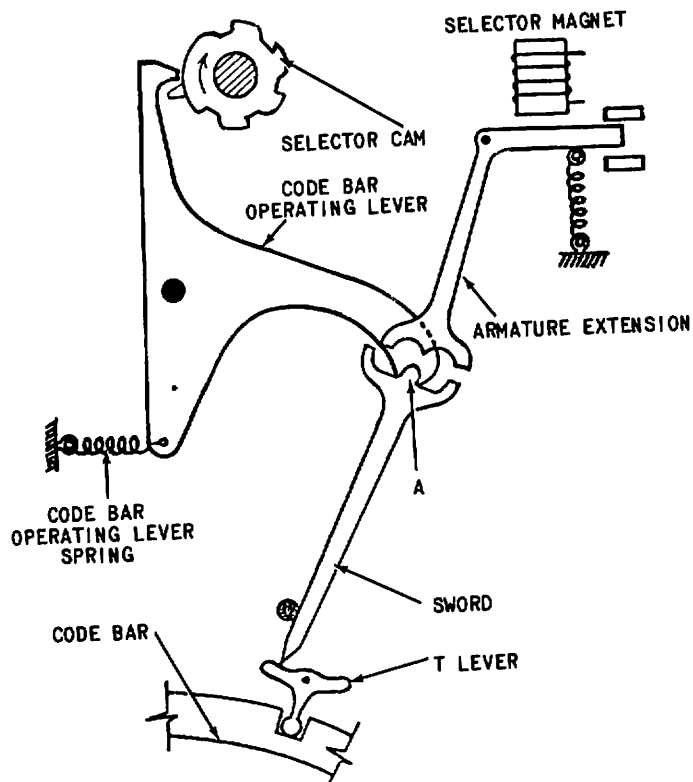
(b) Perforators are normally used in large centers where the volume of traffic makes their use necessary. The great advantage of this equipment is that its speed is only limited by the ability of the operator, and that it requires no associated equipment for operation except a power source. In direct keyboard transmission, the operator's speed is limited to the standard speeds of equipment and lines (usually 60, 75, or 100 words per minute). However, the perforator is an off-line machine, i.e., it is disassociated from the signal line. A perforator is equipped with a free speed keyboard, and trained operators can attain extremely high speeds. Also, less skilled operators can prepare tape for transmission without wasting circuit time.

(c) The perforator is comparatively light and portable, and consists essentially of a set of keys, key-levers, and perforating, tape-feeding, and end-of-line indicating mechanisms. The motive force necessary to operate the perforating mechanism is applied by a pair of solenoid-magnet coils. The unit is equipped with a power cord, and a source of 110 volts DC is required for its operation.

(d) The signaling code used in perforating tape is the 5-unit code. The keyboard of the perforator resembles that of a page-printing teletypewriter, or a reperforator equipped with a keyboard. When depressing the keys of a perforator or teletypewriter, the same function is performed; the code is translated into characters on the punched tape. The code, similar to that transmitted by other teletypewriter equipment, consists of five selecting pulses used in the various combinations of marking (current) and spacing (no current) intervals. Large code holes in the punched tape represent marking pulses; positions on the tape where there are no perforations represent spacing pulses. The small holes in the tape are used to feed the tape through the perforator. In fully perforated tape, the cuttings are called chad. In printed chadless tape the perforations remain hinged so as to provide a printing surface. Figure F-13 shows a sample of a perforated tape.

2.3 Transmitter Distributors (Tape Readers)

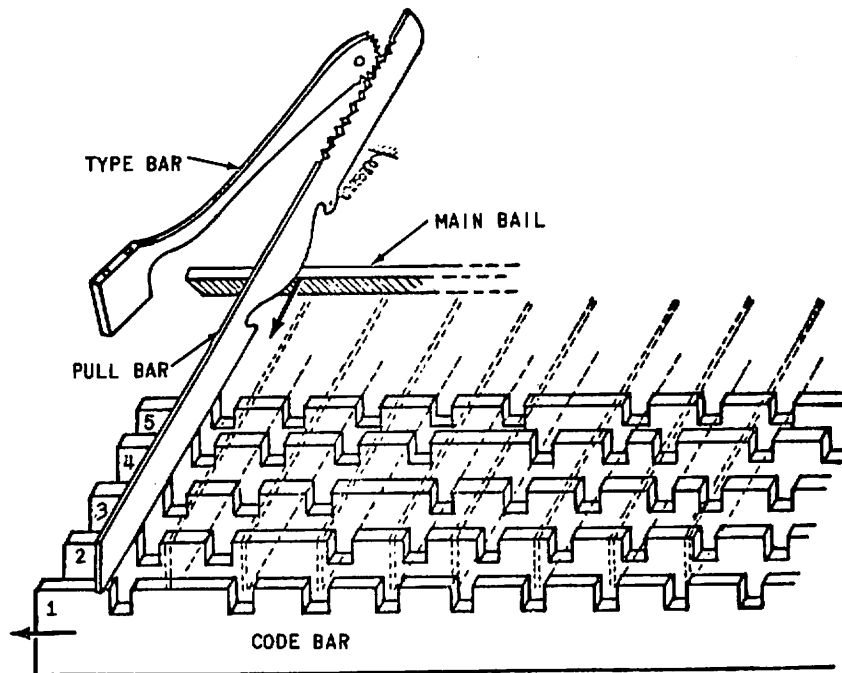
A transmitter distributor or tape reader is a motor-driven device which translates code perforations recorded on paper tape into electrical pulses, and then transmits



(From *Electrical Engineer's Handbook* by Pender and McIlwain, New York, 1950.
Used by permission of John Wiley & Sons.)

**TELETYPEWRITER RECEIVING SELECTOR MECHANISM,
ILLUSTRATING POSITIONING OF CODE BARS**

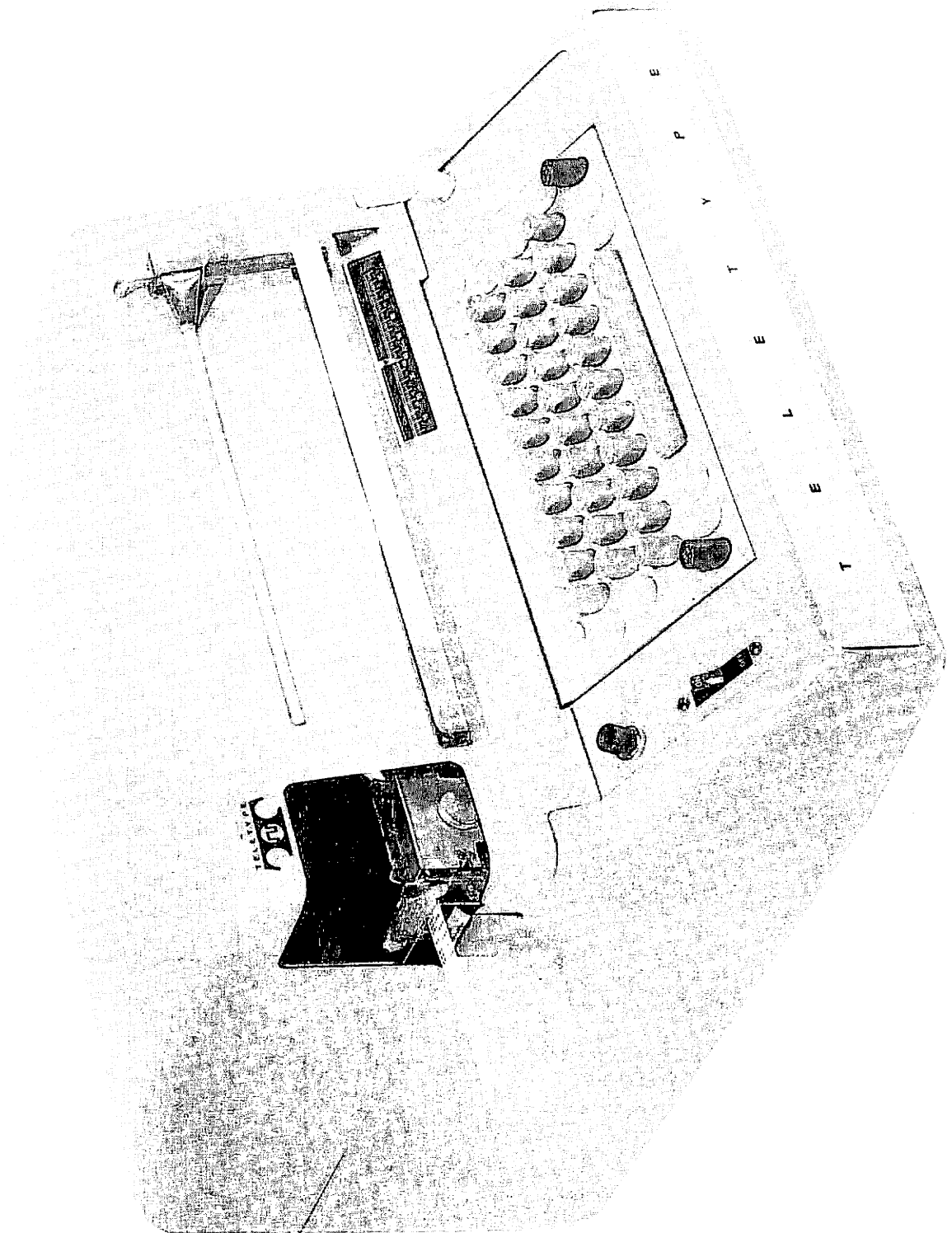
FIGURE F-10



(From *Electrical Engineer's Handbook* by Pender and McIlwain, New York, 1950.
Used by permission of John Wiley & Sons.)

**TELETYPEWRITER RECEIVING MECHANISM, ILLUSTRATING
SELECTION OF SYMBOL**

FIGURE F-11



(Photograph courtesy of Teletype Corporation.)
NON-TYPING PERFORMER (TAPE PUNCH), MODEL 28
FIGURE F-12

these pulses as a 5-unit, start-stop teletypewriter code to one or more receiving stations. The operator inserts the tape, turns the switch to start, and transmission is under way. Once started, the tape feeds automatically. Electrical pulses produced by a transmitter distributor are suitable for transmission by wire lines or by the addition of certain accessory equipment, through the medium of radio. Figure F-14 shows a typical single-channel transmitter distributor. The transmitter distributor is the basic tool for moving information, which has been coded into punched tape.

Single channel tape readers usually provide for five or six code combinations, transmitted sequentially. Other tape readers are available that will handle 5-, 6-, 7-, or 8-track codes, and translate the code combinations from perforated tape into electrical pulses for simultaneous output on a parallel wire basis. The multiple-tape reader is designed to save space when a number of transmitter distributors are required; three or six units are compactly packaged with a single motor. The multiple reading heads may be operated at one time, feeding different locations simultaneously, or an automatic-start feature permits successive transmission from the various tape gates.

2.4 Reperforators (Tape Punches)

2.4.1 General. The reperforator or tape punch is a receiving perforator. These are motor driven devices containing selector mechanisms, designed to receive messages in the form of electrical pulses and record them by punching tape. Some units also type the characters on the tape so that the tape can be read by anyone and handled easily. To accommodate the printing, the tape produced is the partially punched chadless variety. Some of the tasks this machine performs are the following:

(a) Message relaying—at central points, for the interchange of traffic between locations not connected by direct wire.

(b) Monitoring—providing a record in storable form of all traffic transmitted from a station.

(c) Integrating data—combining information from several sources into a single tape.

(d) Reproducing tapes—for multiple address messages and wherever duplicate tapes are needed.

Descriptions of various types of reperforator units are given in the following paragraphs.

2.4.2 Sending-Receive Typing Reperforator. This type of reperforator is equipped with a keyboard base. Operation of the keyboard at a home station sets up electrical pulses, which start a simultaneous dual action. The pulses go out over the line to one or more distant receiving machines; at the same time, the pulses actuate

perforating mechanisms of a home-station typing reperforator recording the outgoing message on tape. Therefore, messages may be transmitted as electrical pulses directly from the keyboard to another machine, or the perforated tape may be fed into transmitter distributors for transmission.

2.4.3 Receive-Only Typing Reperforator (Figure F-15). A receive-only typing reperforator is approximately the same size and weight as a sending-receiving typing reperforator, but it is not equipped with a keyboard base; this type of reperforator is used only for receiving. Normally, a receive-only typing reperforator is used as a part of a complete teletypewriter set or system, and not as an independently operated unit. The method of tape recording provided by this unit bears the message both in typewritten form and in code perforations, which makes this type of reperforator particularly useful in message and relay centers, where a great amount of traffic (both original and relayed) must be handled with a minimum of delay.

2.4.4 Receive-Only Nontyping Reperforator. The receive-only nontyping reperforator is similar to the typing reperforator in operational theory, but differs considerably in construction and usage. Because it is used only for receiving, it contains no keyboard and records messages only by code perforations. Generally, the nontyping reperforator is used in communication center installations where the perforated tape is fed directly to a transmitter distributor and visual reading is not required.

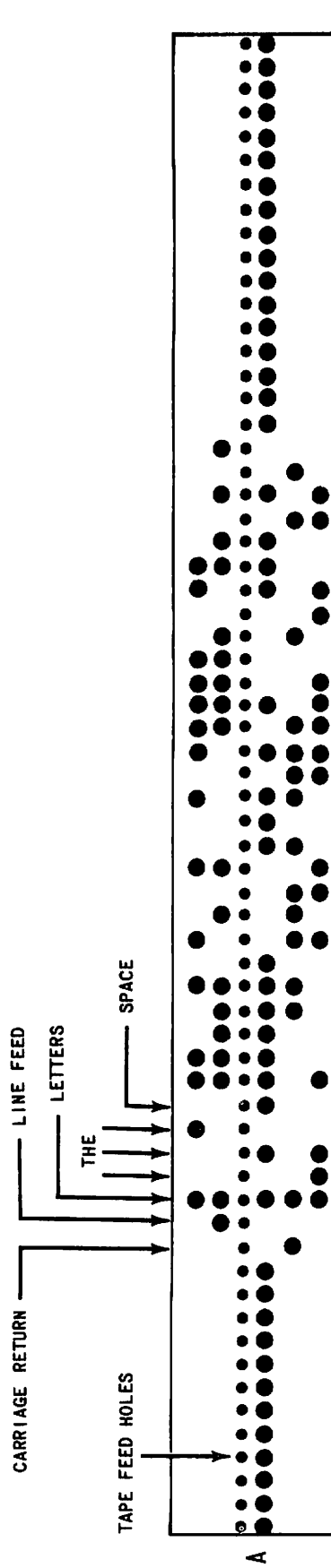
2.5 Consolidated Sets

2.5.1 General. The page-printing teletypewriter, perforators, transmitter distributors, and reperforators may be used together as various combinations to form consolidated sets. In most cases, these pieces of equipment have been dealt with previously as individual units. Descriptions and uses of such sets are covered in the following paragraphs.

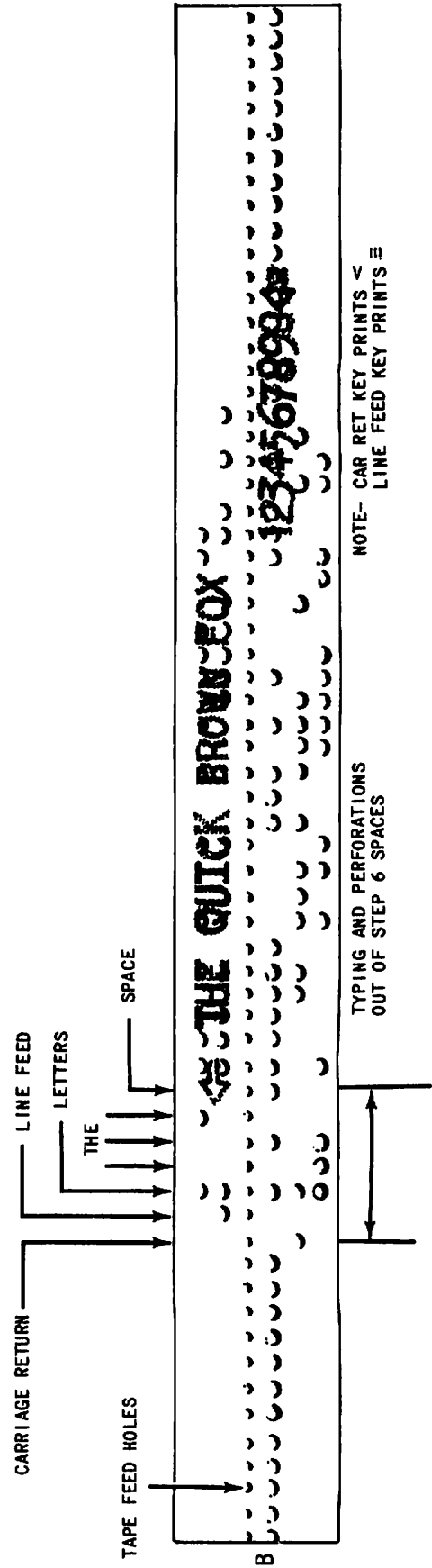
2.5.2 Automatic Send-Receive Set (ASR). The ASR is made up of a group of basic component units as shown in Figure F-16. These units include a keyboard, page printer, tape punch, tape reader, electrical service unit, console, and motor. An automatic send-receive control knob can select any one of three operating conditions.

(a) Keyboard Setting—The keyboard can be used to transmit messages directly to another station or groups of stations. A record of the messages is made available on the local page printer.

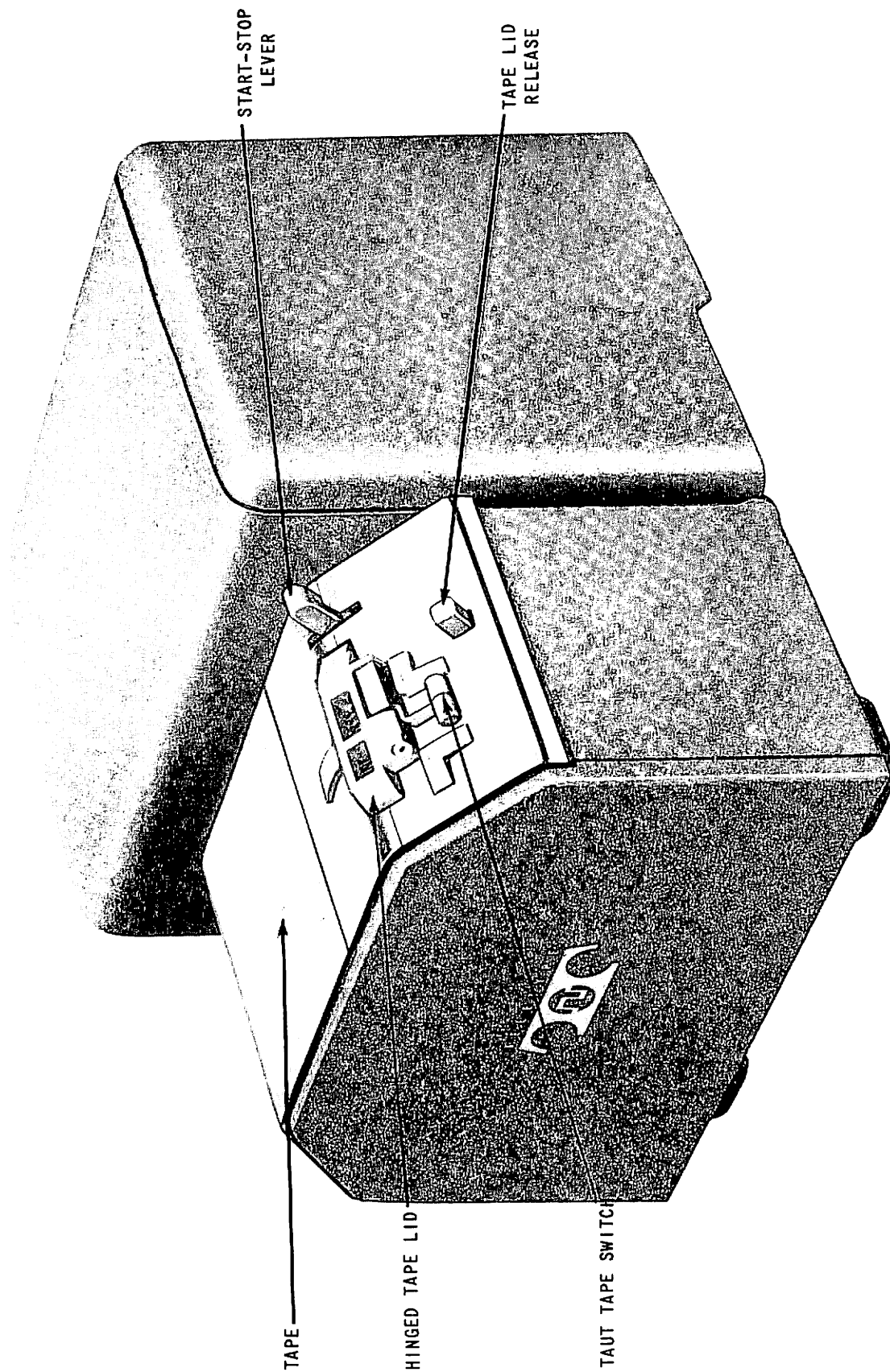
(b) Tape Setting—The keyboard can be used for direct mechanical perforations of tape at speeds in excess of 100 wpm. The page printer is available for the



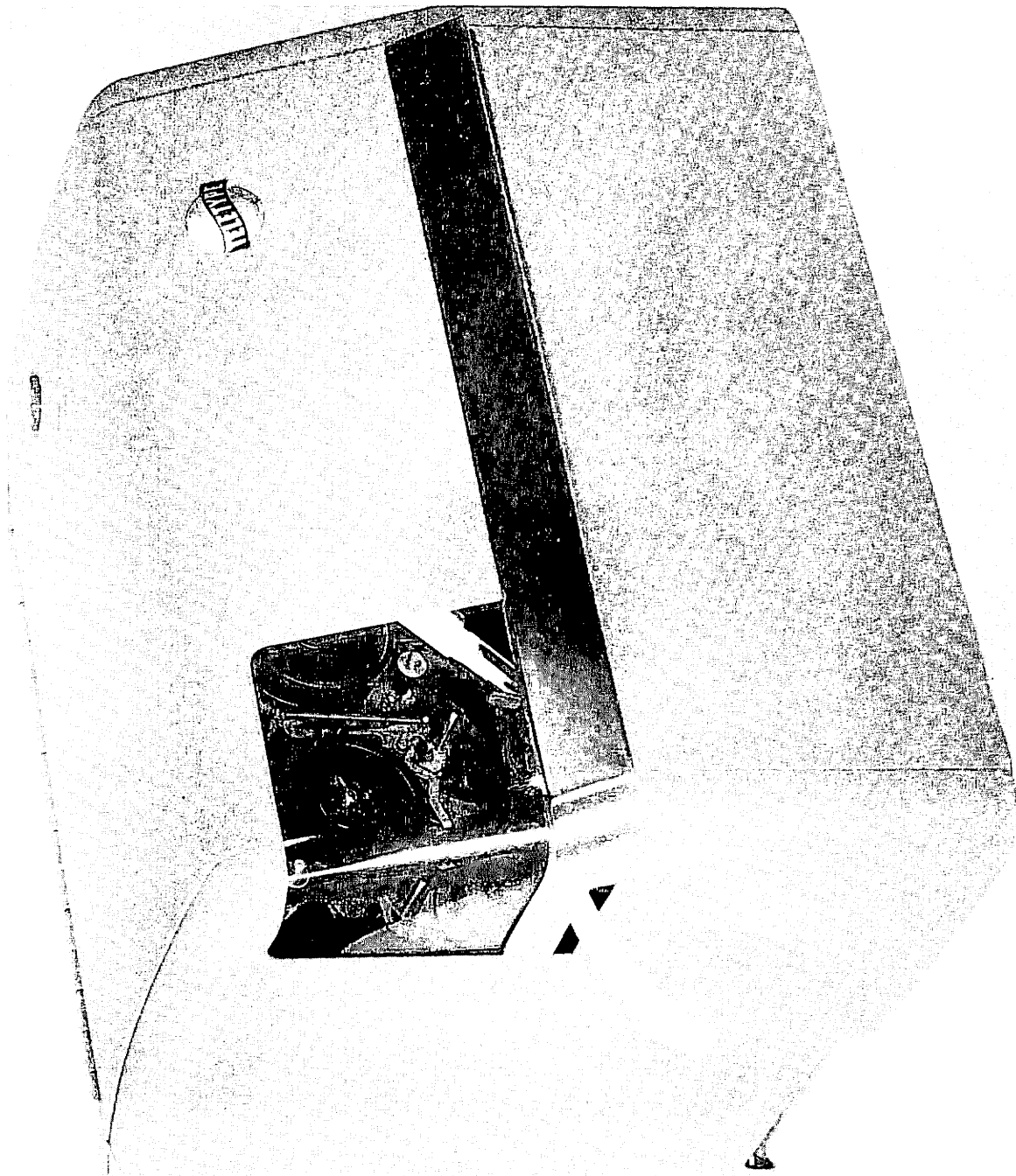
F-19



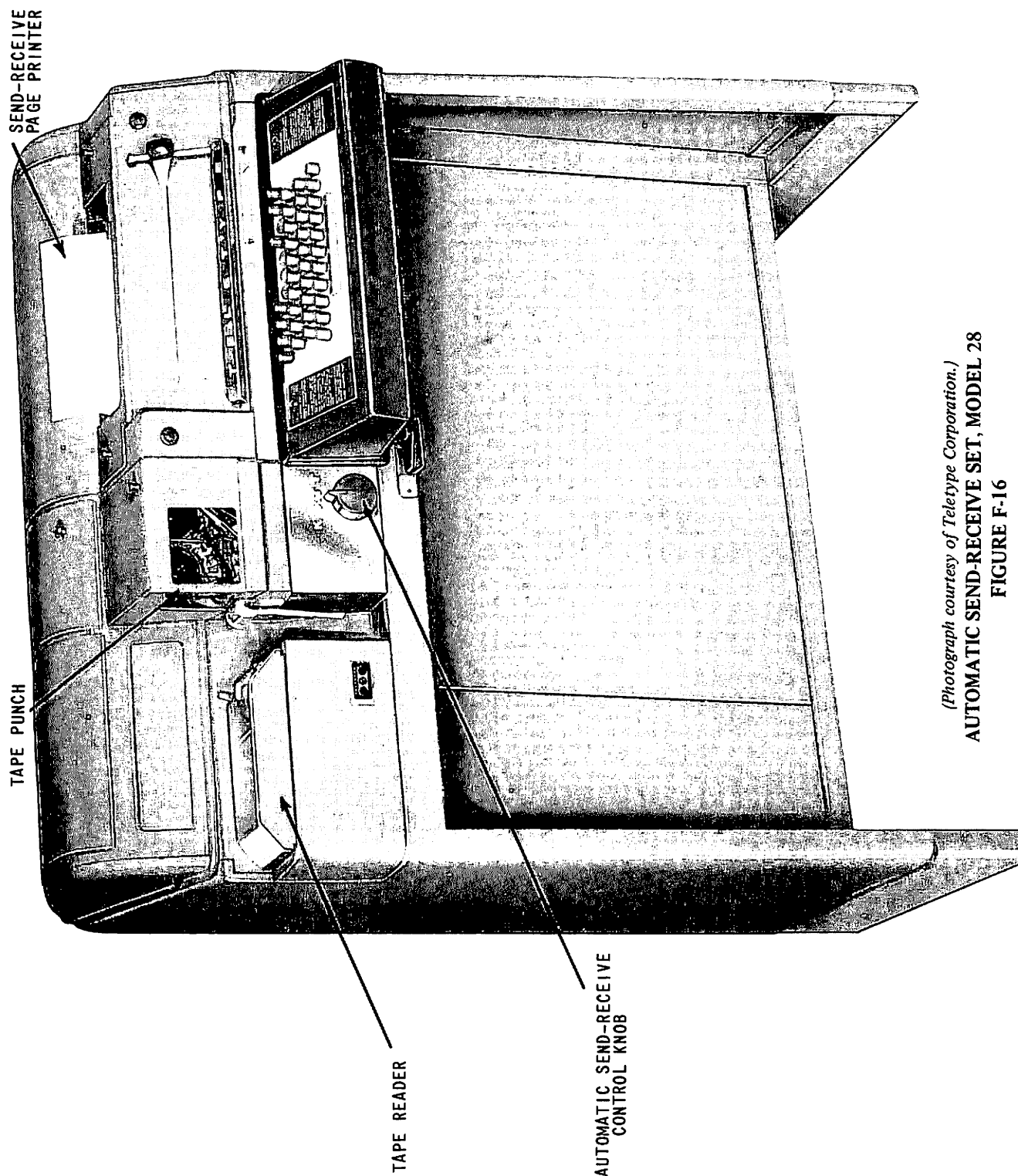
SAMPLES OF CHAD AND CHADLESS PERFORATED TAPES
FIGURE F-13



(Photograph courtesy of Teletype Corporation.)
TRANSMITTER-DISTRIBUTOR (TAPE READER) MODEL 28
FIGURE F-14



(Photograph courtesy of Teletype Corporation.)
RECEIVE ONLY – TYPING REPERFORATOR (TAPE PUNCH), MODEL 28
FIGURE F-15



(Photograph courtesy of Teletype Corporation.)
AUTOMATIC SEND-RECEIVE SET, MODEL 28
FIGURE F-16

receipt of incoming messages or to monitor transmission from the transmitter-distributor.

(c) **Keyboard and Tape Setting**—The keyboard can be used to perform the dual operations of transmitting messages electrically while simultaneously perforating tape by mechanical means.

Various single contact and multicontact tape readers, as well as typing and nontyping perforators and reperforators, can be applied in the above automatic send-receive set to accommodate specific needs.

2.5.3 Reperforator-Transmitter Set (RT Set). An automatic tape reperforator transmitter-distributor is shown in Figure F-17. This device provides for receiving, sending, and tape handling in one package.

(a) **Receiving Unit**—A typing tape punch will receive incoming message at speeds of 60, 75, or 100 wpm. Gears are available for the various speeds required.

(b) **Sending Unit**—A tape reader component will read tape from the tape punch component and transmit either sequential or parallel-wire electrical pulses at speeds ranging from 60, 75, 100, or 200 wpm.

The above combination is used for cross-office relaying through automatic switching centers. The RT set will provide facilities for receiving incoming signals, and relaying them to another RT set for retransmission over a selected line. Intermediate storage will provide for incoming messages to be received and stored temporarily when the outgoing line is busy. The set will receive and store the information on tape, and automatically transmit the information when an outgoing line is available.

2.6 Telegraph Repeaters

2.6.1 General. A telegraph repeater is a device which amplifies or reshapes and/or retimes an input signal for further retransmission. As the length of any line is increased, a point is finally reached at which attenuation becomes greater than can be tolerated in a satisfactory communication channel. Such extension of the length requires the addition of amplifiers to the line. An amplifier receives the weak, attenuated signal from one section of line, and sends out a strong replica of it into the next section. In this process, the amplifier gives new power to the signal. This feature is quite different from the effect of loading, which merely decreases the amount of the original signal power that is lost in the line.

Amplifiers are 1-way, whereas communication circuits are usually 2-way. Two amplifiers are required, one each for amplifying the signals traveling in each direction. The two oppositely directed amplifiers at a given point, with their associated equipment, are called a repeater.

DC telegraph repeaters are classified broadly as terminal repeaters, intermediate repeaters, and regenerative repeaters.

2.6.2 Terminal and Intermediate Repeaters. For long distances, telegraphy usually employs carrier methods similar to those of telephony, i.e., electronic amplifiers or repeaters are used.

While most long-haul telegraph traffic falls in the AC category, the telegraph signals at their ultimate terminal, whether sending or receiving, are DC. Transmission over the loops extending from the central offices to the subscriber is usually by DC. In some cases, it is necessary to employ some kind of DC repeating device at the terminal offices, or at some intermediate point to counteract the DC line or loop losses. The device used depends upon the weakened signal pulses to operate a relay and connect a fresh battery to the line.

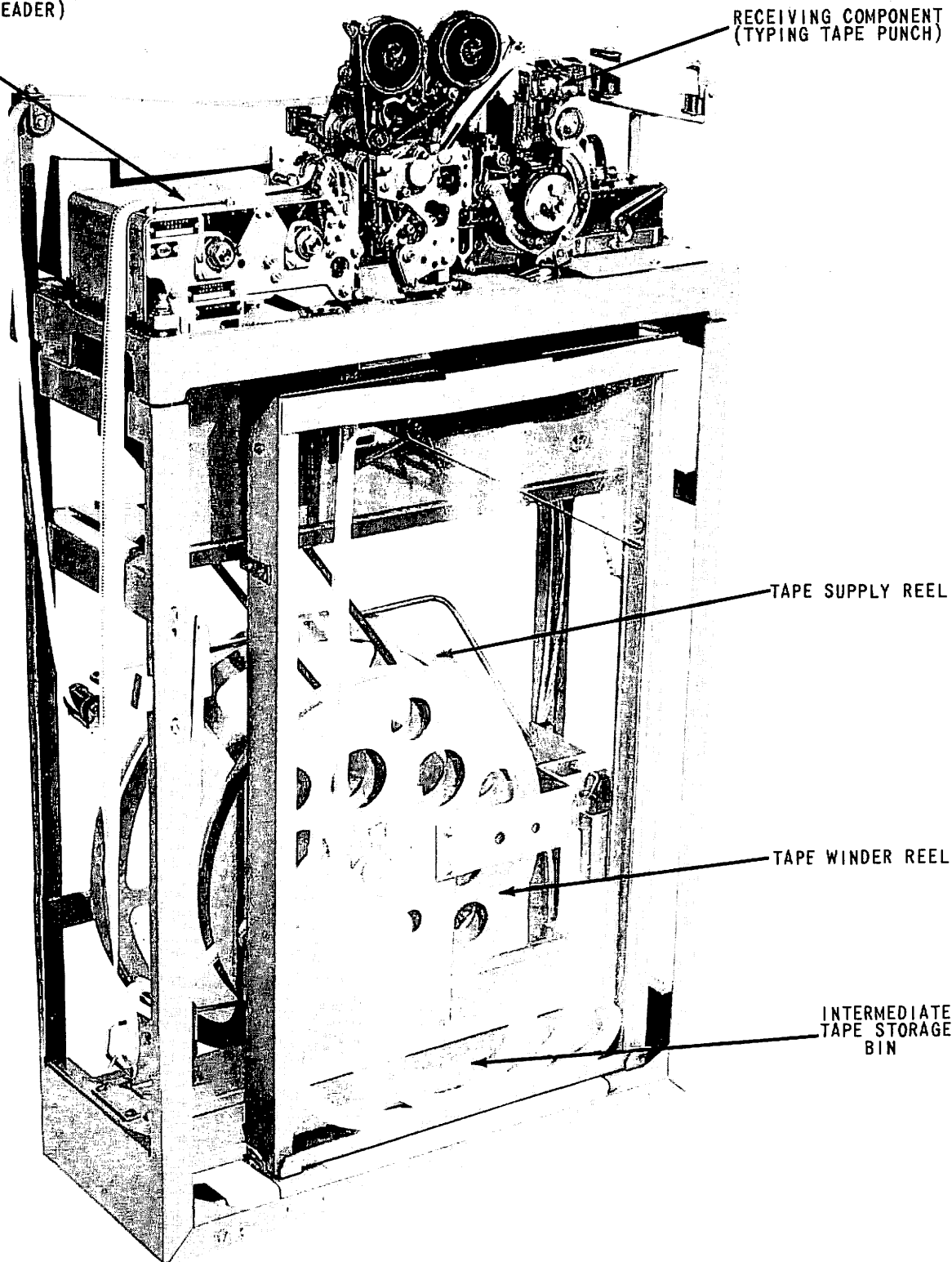
These units are devices that provide means of extending the range of DC keying circuits beyond the maximum distance range usually associated with such a signal. They are used to improve the transition waveform of either polar or neutral DC telegraph signals, and to isolate or provide an additional battery to the telegraph line. Electromechanical (polar) relays are the most common form of telegraph repeater; they do not contain timing or selective components and, when properly adjusted, have no effect on the timing of signal pulses. A repeater receives the attenuated signals at the end of a section of a line, and retransmits them at their original (or other) current value to the next section of the line. The repeater thus restores the abrupt nature of the signaling changes present in the original signal. It must be realized, however, that the repeater cannot correct any time distortion which may be present in the received signal.

Figure F-18 shows the arrangement of repeaters suitable for use in 2-way simplex circuits. From the diagram, it will be seen that the lines from the terminal stations terminate on polar relays at the repeater station. These relays function as retransmitting relays to the next section of the circuit. The attenuated signals are sufficiently strong to operate the relays, and these in turn retransmit the same, or any other battery power, to the next section of the line. Ample current strength to operate the relays at the terminal stations is thus maintained in the circuit.

Electronic telegraph relays are used for high-speed keying applications, such as repeating time-division-multiplex signals. Both types of nonregenerative repeaters are used in various combinations to satisfy special requirements, such as polar-to-neutral conversion, 2-wire to 4-wire conversion, and multiple keying of separate equipments.

SENDING COMPONENT
(TAPE READER)

RECEIVING COMPONENT
(TYPING TAPE PUNCH)

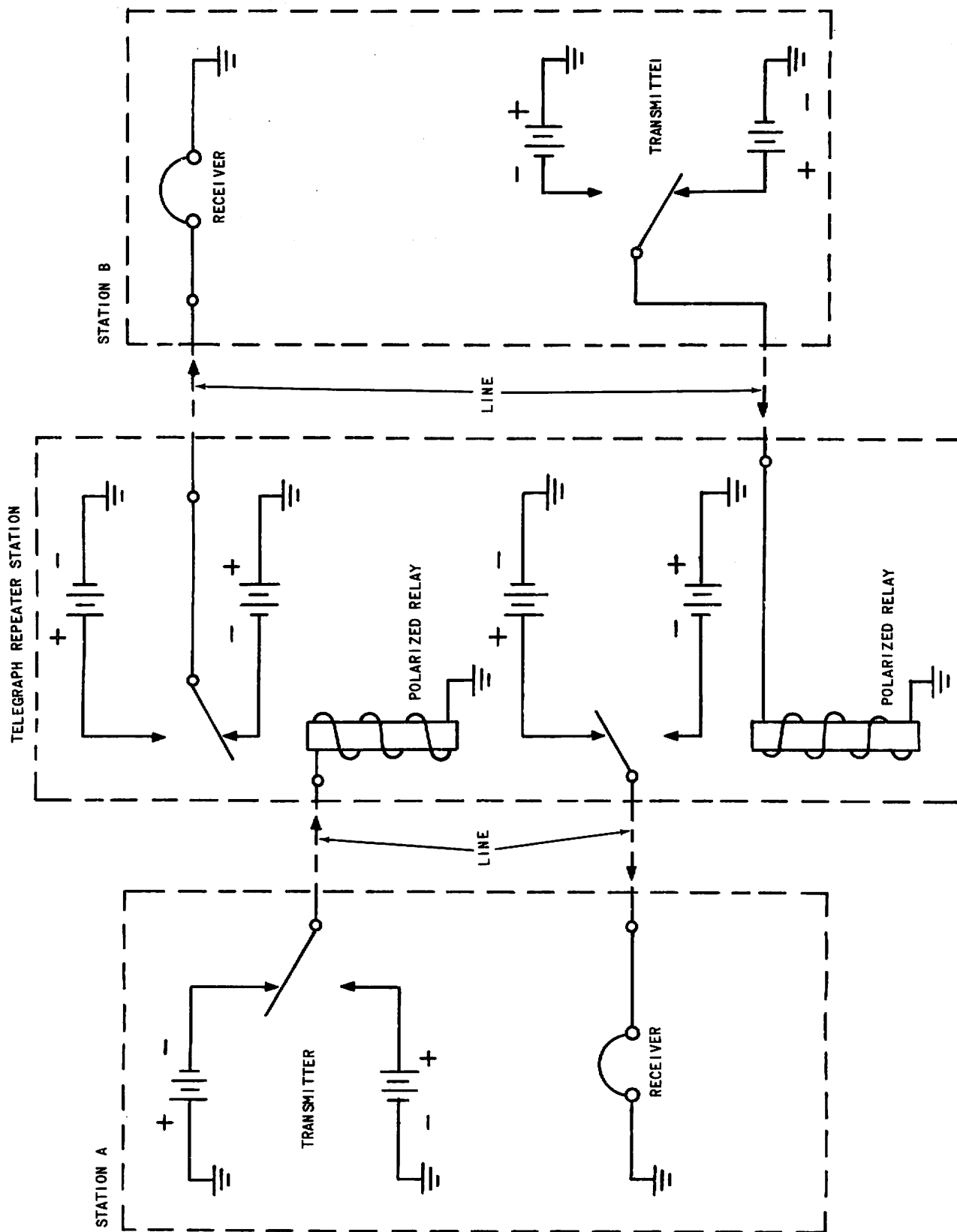


(Photograph courtesy of Teletype Corporation.)

REPERFORATOR-TRANSMITTER-DISTRIBUTOR, MODEL 28

FIGURE F-17

F-24



TELEGRAPH REPEATERS (NONREGENERATIVE) USED IN A 2-WAY SIMPLEX CIRCUIT
FIGURE F-18

2.6.3 Regenerative Telegraph Repeaters. These units receive a distorted telegraph signal and reform and retime the signal to a standard quality for retransmission along the network. Telegraph equipment generally is designed to accept a great deal of distortion in the incoming signal, and for this reason, regenerative repeaters usually are not used at terminal stations. However, if the signal is relayed along the network, regenerative repeaters should be provided at relay points. In this way, the signal received at the destination is distorted only by the amount picked up following the last repeater in the system. (Refer to Part B, paragraph 4.7 of this manual, Telegraph Transmission Coefficients.)

The high-speed operation commonly used with teletypewriters is possible only if the total distortion of the received signals is held within prescribed limits. Telegraph signals are invariably distorted to a greater-or-less extent in the process of transmission, and ordinary telegraph repeaters repeat the greater part of such distortion, so that it increases cumulatively with the length of the overall circuit; therefore, the maximum distance over which a teletypewriter circuit can be operated tends to be limited. Fortunately, the fact that the signals are of standard length and are transmitted with mechanical uniformity permits the use in long circuits of a regenerative repeater, which is capable of eliminating distortion from the signals.

The primary function of such a repeater is to retime and retransmit the received signal pulses. It is capable of receiving without error any set of signals that would be satisfactorily received by an ordinary teletypewriter, and of sending these same signals out exactly the same as the signals produced by the sending teletypewriter.

Figure F-19 shows schematically the simplified arrangement of an early type of regenerative repeater employing a flat distributor face and rotating brush arm. Here the two outer segment rings represent the receiving commutator face, and the two inner rings the sending commutator face. The segments of the receiving commutator are shorted together consecutively by a pair of brushes. At the same time, the segments on the receiving commutator are shorted together by a second set of brushes. Both sets of brushes are mounted on a common rotating brush arm. To follow its operation, let us assume that the letter R is to be transmitted. We find that the incoming signals will consist of the starting space pulse, a space, a mark, a space, a mark, a space, and the final marking stop pulse. As the starting space pulse is received, the brush arm will be released (through a mechanism not shown in the drawing), and the two sets of brushes will start to rotate. The receiving brush passes first over a blank segment, and then connects the short No. 1 receiving segment to the receiving relay

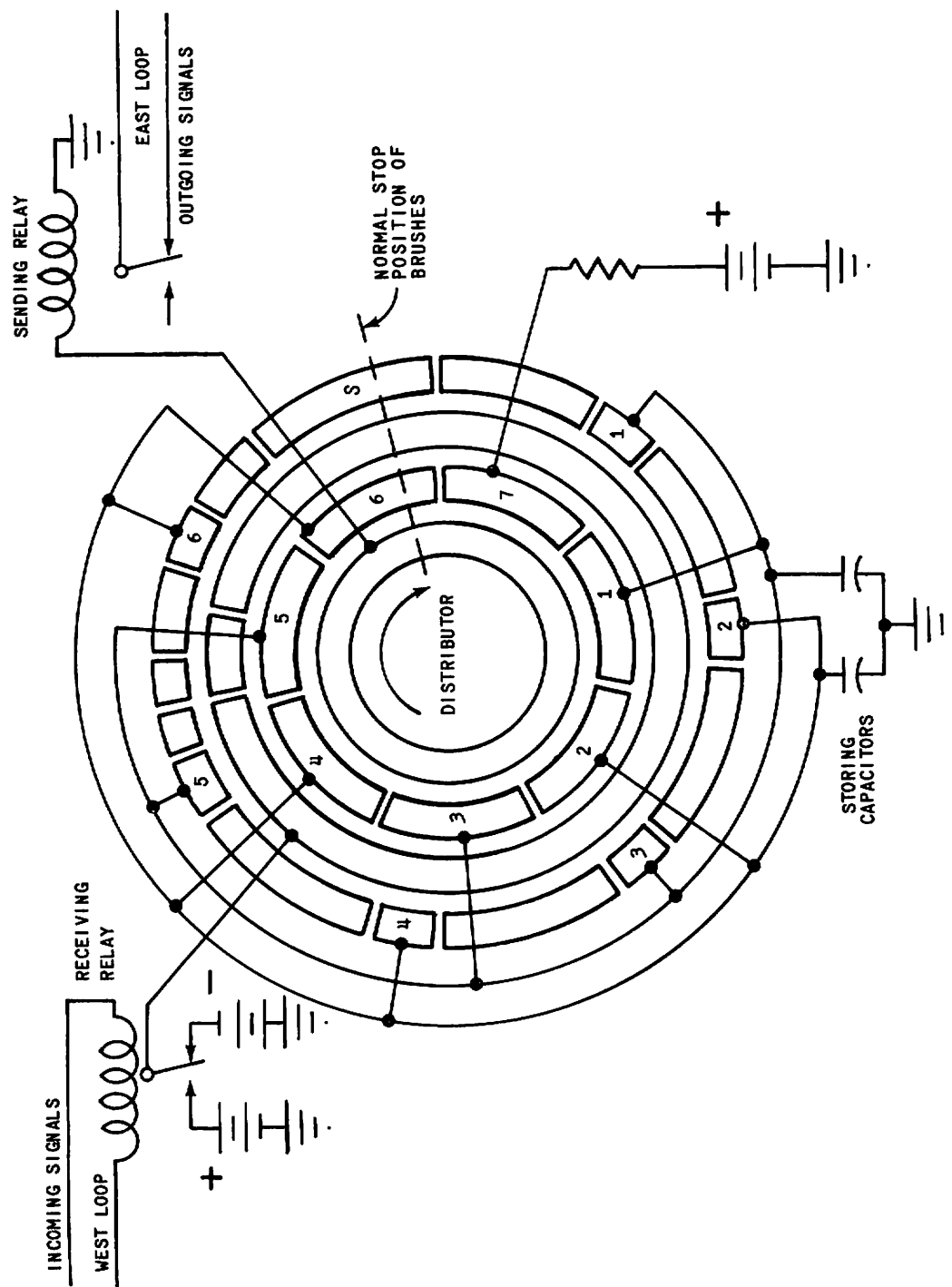
armature. This occurs at the instant that the first spacing signal of the 5-pulse code is being received, and the receiving relay is therefore operated to its spacing contact. The right capacitor will accordingly be charged positive (+). In the meantime, the brush of the sending face has moved over segment 7, connecting spacing battery to the sending relay, and so repeating the start signal to the line in the other direction. Just after the receiving brush moves off No. 1 segment onto a blank, the sending brush moves onto No. 1 segment of the sending face, and the positive charged capacitor discharges through it to the sending relay, thus repeating the first code spacing signal. During this operation, the receiving face brush moves onto segment No. 2 of the receiving face and charges the left capacitor negative (−), in accordance with the incoming marking signal. This capacitor is in turn discharged through No. 2 segment of the sending face, while the right capacitor is being charged through No. 3 segment of the receiving face. This alternate operation continues until all five of the receiving code pulses and the final stopping mark pulse have been repeated to the outgoing line. As it completes its revolution, the brush arm is stopped until the next starting pulse is received.

The fundamental value of the repeater lies in the fact that the short receiving segments pick up only the midportion of the incoming signal, thereby allowing for considerable distortion. The signals sent out are uniform and of equal length because the sending face segments are of equal length, and spaced in exactly the same way as those of the regular sending distributor at the sending teletypewriter. Therefore, it is apparent that the repeater will receive, and convert to perfect signals, any signals that are good enough to operate an ordinary receiving teletypewriter.

Other designs of regenerative telegraph repeaters, now in general use, obtain the same results as discussed above through the employment of various electronic circuits and devices.

2.6.4 Electronic Regenerative Repeaters. Electronic regenerative repeaters are tube or transistorized modules employed to reshape and retime teletype and data transmission media, which have been distorted by the peculiarities of transmission.

These regenerative repeaters will correct input signals having as much as 49 percent distortion, with a maximum of approximately 1 percent output signal distortion in the retransmitted signal. The units are so constructed that all routine adjustments may be made from the front panel. Front panel controls for coarse and fine adjustments are provided for standard speeds; 60-, 75-, and 100-wpm signals.



(From Principles of Electricity as applied to Telephone and Telegraph
Used by permission of American Telephone and Telegraph.)

PRINCIPLE OF THE REGENERATIVE REPEATER

FIGURE F-19

Plug-in modules are available to adapt the repeater to other speeds and codes up to 3,000 wpm; the code is adjustable up to 16-unit start-stop. Electronic regenerative repeaters are designed for long-term reliable performance with a minimum of attention. The basis of the regenerative repeater is a binary chain, driven by a crystal-controlled oscillator (timer), which is inhibited by the data input. This in turn causes timing pulses to be applied to the converter chain, and then fed through a reshaping and retiming network for regeneration.

2.6.5 Repeater Spacing. In addition to changing the type of signals required in various circuit combinations, repeaters are used in long circuits where the signals will otherwise be too weak to operate the receiving equipment. Because of the varying amounts of resistance, capacitance, etc., in the different types of wire and cable circuits, the spacing of repeaters will depend upon both the circuit loss in signal strength, and the capabilities of the repeaters used. Telegraph transmission coefficients (Part B, paragraph 4.7) can be used to determine proper repeater spacing.

Theoretically, each repeater could have a gain equal to the loss of the line section ahead of it, so that it restores all the power that was lost in the line. If this were done, the length of the line could be extended indefinitely. Actually, there are complications that make this impossible, and place definite limits on both the length and the minimum net loss of repeater circuits. Economy of equipment makes it important for repeaters to be placed as far apart as possible. However, this too is limited by practical considerations. Repeater balance on 2-wire circuits and noise and crosstalk on all circuits are factors that restrict the permissible gain of repeaters and, therefore, the distance apart that they may be installed.

2.7 Modulation Rate Converters (MRC)

Modulation rate converters are devices whose basic purpose is to change the input/output modulation rate relationship. (See Figure F-20.)

Modulation rate converters are sometimes called code speed converters, and have been designed to provide an interface between teletypewriter circuits operating at different baud rates. It also may be used to provide a storage and release function for unsynchronized signal sources working into crypto, or other equipments requiring a character step pulse of the sending device. Since speed is converted down as well as up, control feedback, acting the same as a step signal, is provided to the sending device to prevent the incoming character rate from exceeding the outgoing character rate. In addition, an external character release mode is provided

when it is desired to synchronize the outgoing character with external equipment providing a step signal.

The modulation rate converter eliminates teletypewriter gear changing when circuits operating at different speeds are to be accommodated by one machine. The modulation rate converter finds application in areas involving the electrical connection between 45.5- and 75.0-baud teletypewriter equipment.

The modulation rate converter may be used as a signal regenerator, as well as telegraph speed changer. The converter provides regeneration without error of signal input distortion up to 45 percent.

3.0 CURRENT TRENDS IN EQUIPMENT DESIGN

3.1 Application Highlights (Paper Tape)

Paper tape is a widely used medium for input to computers and communication systems. It has been used for many years as an input and output medium for telegraph systems. More recently, paper tape has been used to record information as a by-product of document preparation of such paper tapes simultaneously with the preparation of documents can eliminate a separate punched card keypunching operation in data-handling procedures and a separate teletype keyboard operation in message communication procedures. The latter practice can result in marked reductions in the costs of preparing information for entry into communication systems. Hence, paper tape is an important medium for the storage of data, serving at the same time as a low-cost input medium.

Information on paper tape is recorded as holes or printed spots in rows across the tape. The holes or spots of each row represent an alphabetic character, a numeric digit, or a control function. The maximum number of holes or spots that can be recorded across the tape is referred to as the number of tracks on the tape and is dependent upon the type of code used. Codes in common use have from five to eight tracks.

In general, punched tape has been found most satisfactory for use where the tape is likely to be manually handled many times throughout its useful life. On the other hand, printed tape has the advantage that it can record information at a much faster rate than punched tape. Printed tape, however, is not as strong mechanically as punched tape because of the chemical composition required for high-speed printing. Consequently, printed tape is limited to those applications that require a minimum of manual handling.

3.2 Paper Tape Readers

Tape readers are manufactured either as independent units or as integrated parts of page printers. Their func-

tion is to provide an electrical output from the paper tape input.

Paper tape readers use one of three sensing techniques: mechanical, pneumatic, or photoelectric. The photoelectric technique can, in turn, be subdivided into transmitted light (or shine-through) models in which light is projected through the tape and reflected light models in which light is reflected from the tape surface.

3.2.1 Mechanical Readers. Mechanical readers are provided with sensing pins, in number equal to the number of levels in the code. While the tape is stationary, the sensing pins press against it and, if perforations are present, one or more pins will pass through, permitting an associated contact assembly to operate and thereby establish an electrical contact.

Mechanical readers are used to read all types of punched tape, including both chad tapes (where the hole or chad is punched completely out of the tape) and chadless tapes (where the hole is only partially punched out of the tape). Mechanical readers are relatively inexpensive and reliable, particularly in the sensing of holes which may be obscured by loose chads, dirt, or lint. The limiting performance factors are reading speed and tape wear. Sensing can be accomplished by spring-loaded pins, star wheels, brushes, or other similar techniques. Figures F-21, F-22, and F-23 present representative sensing techniques.

3.2.2 Pneumatic Readers. Pneumatic readers operate by passing streams of air through any holes in the tapes. Thermocouples sense whether air is passing through a tape hole or not. Advantages of this technique include the ability to read any type of punched tape, the reduction in wear and tear on the tape, a capacity to operate at high speeds, and the ability to read holes whose spacing is outside the tolerance limits of mechanical readers. This type of reader is still new and without the field experience needed to determine service requirements and reliability. There is the possibility that contamination of the thermocouple sensing elements during use may reduce reliability. Refer to Figure F-24.

3.2.3 Photoelectric Readers. The primary advantage of photoelectric readers is their ability to operate at high speeds. Practically all photoelectric readers employ friction drives rather than the sprocket wheel drives used in mechanical and pneumatic readers. As the operating speed is increased, the tape drive mechanism fails before the photoelectric sensor.

3.2.3.1 Transmitted Light Readers

Transmitted light photoelectric tape readers are designed with the light source and sensor on opposite sides of the tape. The signal-to-noise ratio (S/N) is, therefore, the ratio between the response of the photocell to the full intensity of the light source and the light passing

through the tape. It is virtually impossible for photoelectric readers to read chadless tape. Translucent tapes also pose a problem to transmitted light photoelectric readers, since they find it progressively more difficult to discriminate between hole and no-hole as tape opacity diminishes. Oil impregnation of tape (used to lengthen tape punch life) reduces opacity and may reduce S/N below the level required for reliable operation.

3.2.3.2 Reflected Light Readers

Reflected light photoelectric tape readers are designed with the light source and the photoelectric sensors on the same side of the tape. The S/N in this case is the ratio of the response to the change in reflected light between the hole and no-hole conditions. On printed tape, this is the difference between the response to the coded black spots and the white background of the tape. With punched tape, a flat, non-reflecting surface is used behind the holes, thus providing artificial black spots. Reflected light readers have had difficulty in discriminating between black dots, coded holes, and dirty tape marks. One manufacturer claims to have solved this problem by means of a variable-density pickup controlled by a switch, which enables a selection to be made between printed or punched tape.

3.2.3.3 Photo Diodes

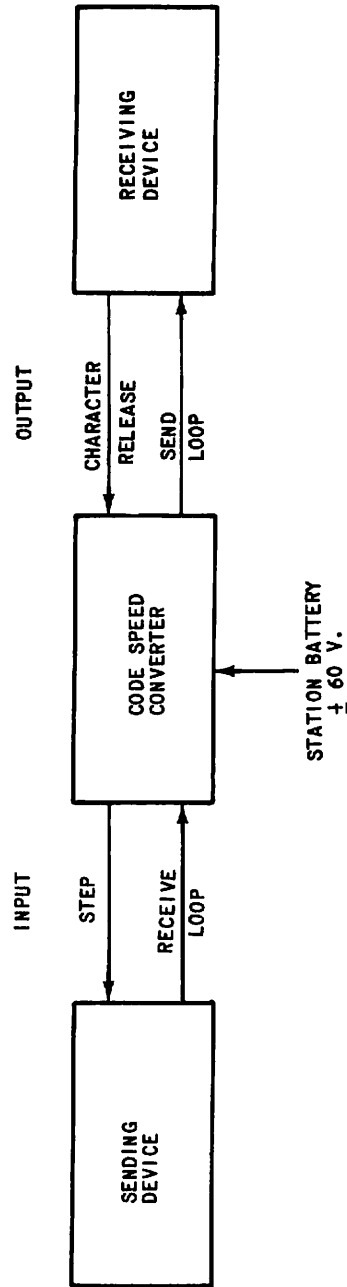
Current photoelectric readers employ silicon cells rather than photovoltaic cells. Reliability is thus improved, since the photovoltaic cells require a warmup period for efficient functioning and apparently are not able to distinguish a hole from a no-hole condition until after this period. A typical photoelectric mechanism is shown schematically in Figure F-25. The nine elements provide eight data channel outputs and one strobe channel output for use with standard 5-, 7-, and 8-track tapes.

3.2.4 Dielectric Sensing Readers. In dielectric sensing readers, the punched tape forms the dielectric of a capacitor whose capacitance is changed as a hole passes the read station. Unlike photocell sensors, dielectric readers are insensitive to environmental dust and low-quality paper. Since lamps and photocells are not used, there is no problem of long-term drift and aging. Refer to Figure F-26.

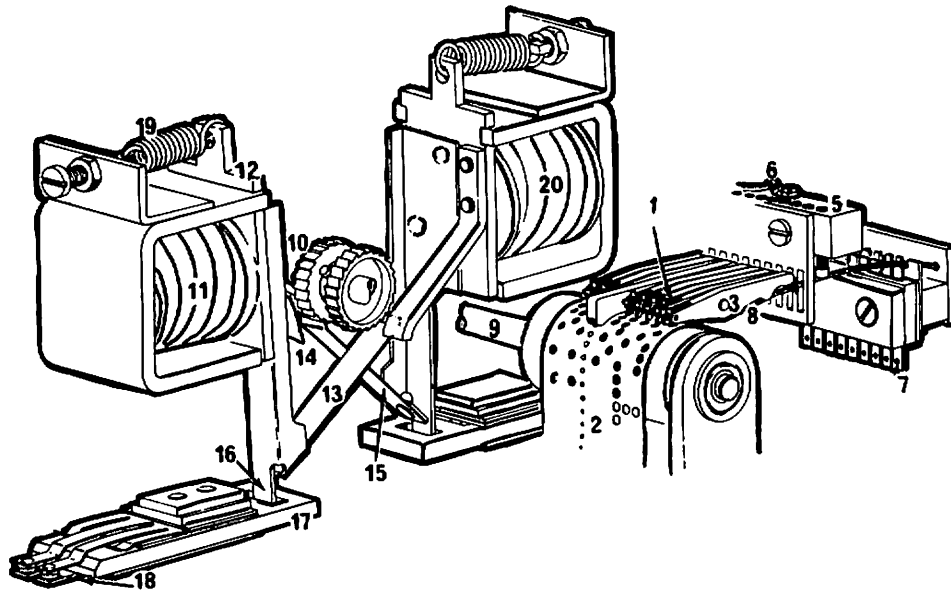
3.3 Paper Tape Recorders

Paper tape has been used for many years as an input and output medium for telegraphic equipment. More recently, paper tape has been used to record information as a by-product of document preparation on an electric typewriter.

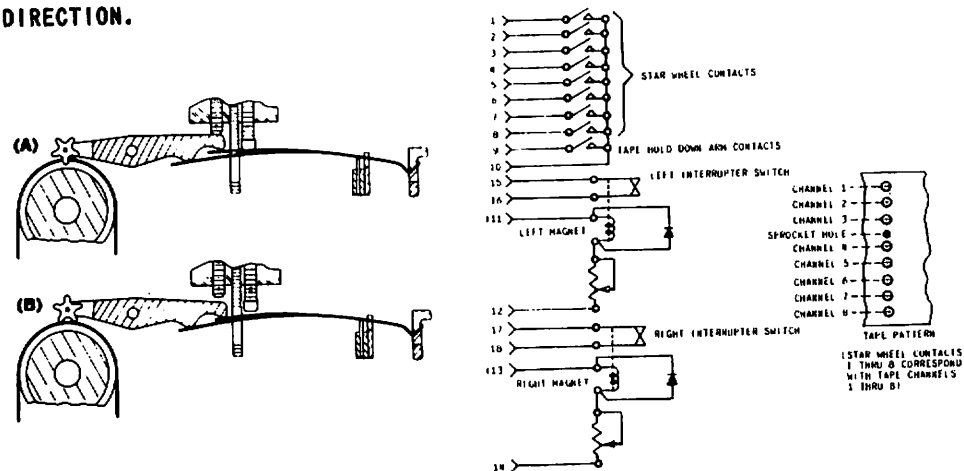
Information on paper tape is recorded as holes or printed spots in rows across the tape. The holes or spots



MODULATION RATE CONVERTER SET-UP
FIGURE F-20

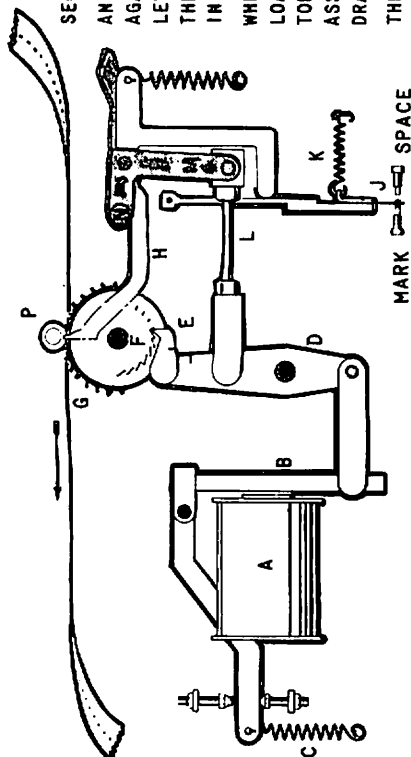


WHEN STAR WHEEL (1) SENSES HOLE IN PAPER TAPE (2), ARM (3) IS ROCKED COUNTER-CLOCKWISE UNDER THE URGING OF CONTACT WIRES (4) WHICH LIMIT ON LOWER SURFACE OF CONTACT SCREW (5). ELECTRICAL CIRCUIT IS THUS COMPLETED FROM COMMON LUG (6) TO LUG (7). LONGER WIRE (8) URGES ARM (3) AGAINST MECHANICAL LIMIT (NOT SHOWN) TO REDUCE BOUNCE. DRIVE SHAFT (9) EXTENDS REARWARD THROUGH PANEL (NOT SHOWN) AND CARRIES B1-DIRECTIONAL RATCHET (10). ENERGIZATION OF COIL (11) ATTRACTS ARMATURE (12) AND ENGAGES PAWL BLADE (13) UNDER NEXT TOOTH. PAWL DEPRESSOR (14) DISENGAGES OPPOSING PAWL BLADE (15). TIP (18) OF ARMATURE MOVES CARD (17) TO OPEN INTERRUPTOR SWITCH CONTACTS (18). UPON DE-ENERGIZATION OF COIL (11), PAWL BLADE (13) STEPS SHAFT (9) UNDER URGING OF SPRING (19). INTERRUPTOR SWITCH RECLOSING NEAR END OF ARMATURE RETURN. PULSING OF OTHER COIL (20) STEPS TAPE IN REVERSE DIRECTION.



THE STAR WHEEL CAN SENSE HOLES IN A PAPER TAPE WHILE THE TAPE IS IN MOTION. AS THE STAR WHEEL ENTERS A HOLE (SEE SKETCH), ITS AXIS IS LOWERED, ROCKING THE ARM CARRYING THE STAR WHEEL IN A COUNTERCLOCKWISE DIRECTION, AND CLOSING THE ASSOCIATED SWITCH (A). WHEN A SERIES OF SUCCESSIVE HOLES IS SENSED, THE STAR WHEEL ROTATES IN MESH WITH THE HOLES, LIKE A GEAR ON A RACK, WITH NO RESULTANT MOTION ON THE CARRIER ARM AND WITH THE SWITCH REMAINING CLOSED. ONLY WHEN THE STAR WHEEL APPROACHES A NO-HOLE AND MOVES UP AND OVER THE TOP SURFACE OF THE PAPER TAPE (B), IS THE SWITCH OPENED.

TAPE READING AND STEPPING MECHANISM OF OHRTRONICS MODEL 119 TAPE READERS
FIGURE F-21



SEQUENCE OF OPERATION

AN INCOMING PULSE TO ELECTROMAGNET (A) CAUSES ARMATURE (B) TO MOVE TOWARDS THE MAGNET CORE AGAINST THE TENSION OF SPRING (C). THIS MOVEMENT IS TRANSFERRED TO RATCHET (F) THROUGH FEED LEVER (D) AND PAWL (E). THE CONSEQUENT ANTI-CLOCKWISE MOVEMENT OF RATCHET (F) IS CONVEYED THROUGH A COMMON SPINDLE TO WHEEL (G). THE PINS ON THIS WHEEL ENGAGE CORRESPONDING HOLES IN THE TAPE, WHICH IS THUS FED FORWARD ONE CHARACTER FOR EACH OPERATION OF THE ELECTROMAGNET. WHEN THE ELECTROMAGNET IS DE-ENERGIZED AT THE END OF THE FEED PULSE, THE TIPS OF THE SPRING LOADED PECKERS RISE TO SENSE THE CODE COMBINATION. PECKERS WHICH PASS INTO A HOLE MOVE TONGUE (J) TO THE LEFT AND CONNECT THE MARK CONTACT TO LINE THROUGH SPRING (K). A TONGUE ASSOCIATED WITH A PECKER WHICH IS HELD DOWN BY UNPUNCHED TAPE, ON THE OTHER HAND, WILL BE DRAWN TO THE RIGHT BY SPRING (K), SO CONNECTING THE SPACE CONTACT TO LINE.

THE NEXT PULSE TO ELECTROMAGNET (A) CAUSES THE TAPE TO BE FED FORWARD TO BRING A NEW CHARACTER TO THE SENSING POINT. DURING THE EARLY PART OF THE INWARD MOVEMENT OF ARMATURE (B), PUSH ROD (L) CAUSES BAIL ARM (M) TO TURN ANTI-CLOCKWISE. BAIL ARM (M) (A HORIZONTAL ROD MOUNTED ON ARM (N)) DEPRESSES THE PECKERS SO THAT THEY ARE HELD CLEAR OF THE TAPE WHILE THE REMAINDER OF THE INWARD MOVEMENT OF ARMATURE (A) COMPLETES THE TAPE FEED ACTION.

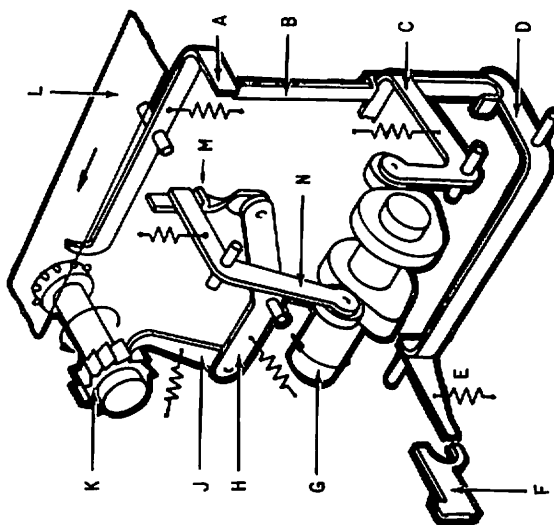
SENSING ACTION

AS THE TRANSLATOR SHAFT (G) REVOLVES, THE PECKER OPERATING CAM CAUSES LEVER (C) TO TURN CLOCKWISE SO RELEASING THE FIVE CODE PECKERS (A) TO SENSE THE UNDERSIDE OF TAPE (L).

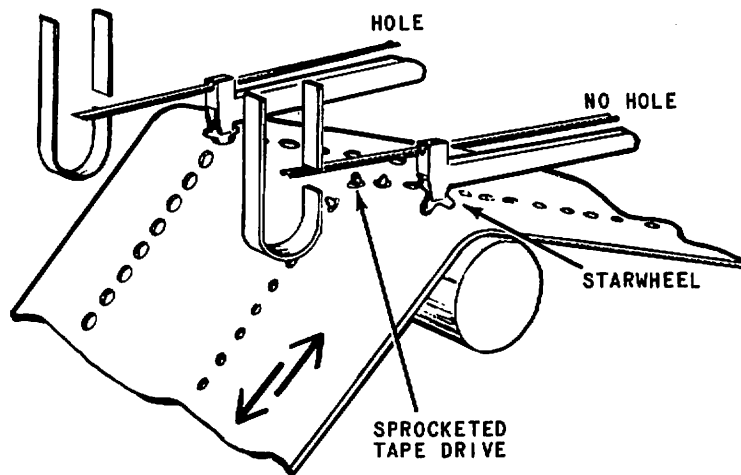
WHEN A PECKER ENCOUNTERS A HOLE (MARK CONDITION) IN THE TAPE, THE ASSOCIATED TRANSFER LINK (B) IS PRESSED DOWNWARDS. THE LOWER END OF LINK (B) ACTS ON INTERPOSER LEVER (D) TURNING IT ABOUT ITS PIVOT SO THAT THE LEFT-HAND END MOVES INTO THE CUT-OUT OF A KEYBOARD COMB BAR (F). THE COMB BAR IS NOW FREE TO MOVE TO THE RIGHT SO SETTING A MARK CONDITION ON THE PIN BOX AS INTERNAL KEYBOARD OPERATION. THE PIN BOX SETTING IS THEN READ OFF BY THE TRANSMITTER AND THE APPROPRIATE ELECTRICAL CONDITIONS ARE CONNECTED TO LINE. IF THE PECKER ENCOUNTERS UNPUNCHED TAPE (THE CONDITION SHOWN IN THE DIAGRAM), INTERPOSER (D) WILL BE HELD DOWN BY SPRING (E) AND THE PATH OF COMB BAR (F) WILL THEREFORE BE BLOCKED. THIS BLOCKED CONDITION ESTABLISHES A SPACE SETTING ON THE PIN BOX WHICH IS EVENTUALLY TRANSLATED INTO A SPACING SIGNAL TO LINE FOR THAT PARTICULAR CODE ELEMENT.

FEED ACTION

THE TAPE FEED ACTION IS DERIVED FROM THE MOVEMENT OF THE CARRIAGE RETURN FUNCTION LEVER (M) WHICH HAS BEEN PROVIDED WITH AN EXTENSION AT ITS RIGHT-HAND END. AS TRANSLATOR CAM SHAFT (G) REVOLVES, THE UP AND DOWN MOVEMENT OF LEVER (M) IS CONVEYED BY FEED LINK (N) AND FEED LEVER (H) TO THE FEED SPINDLE RATCHET DRIVE ASSEMBLY (J) AND (K). A SPROCKET WHEEL ATTACHED TO THE RATCHET SPINDLE DRAWS THE TAPE (L) STEP-BY-STEP THROUGH THE READER IN THE DIRECTION SHOWN IN THE DIAGRAM.



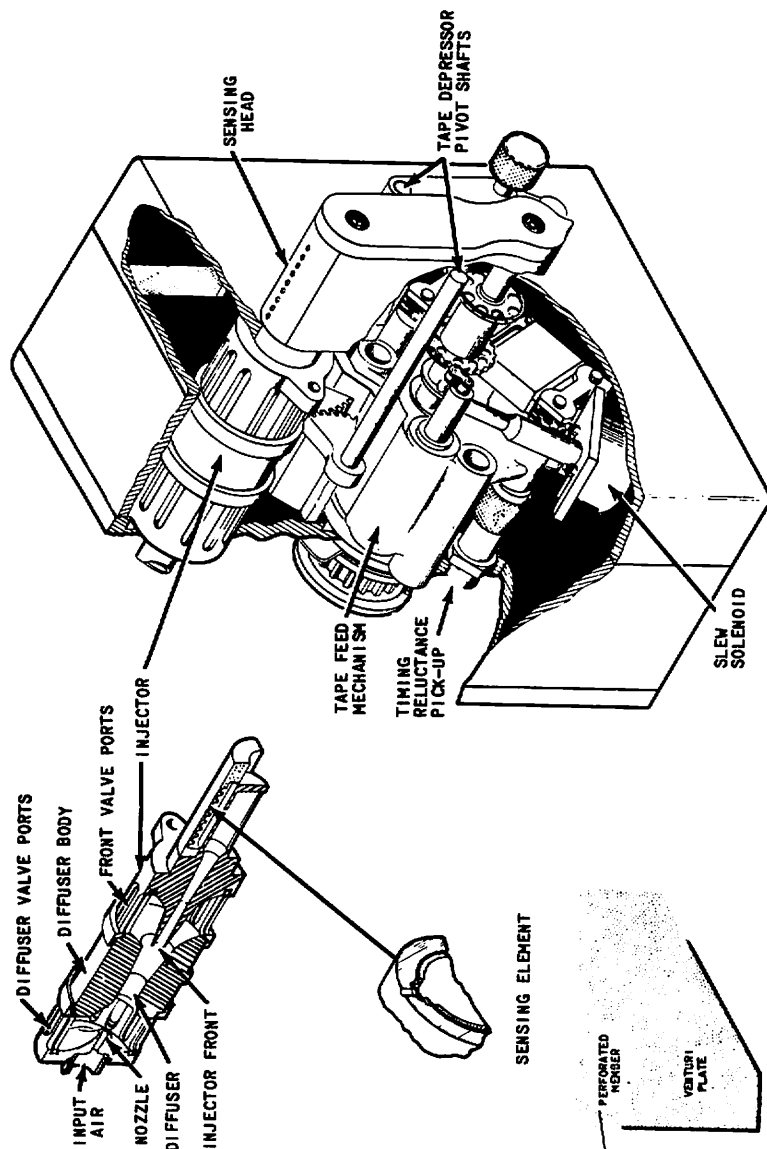
TAPE READING AND STEPPING MECHANISM OF CREED MODEL 92 AND 75 TAPE READERS
FIGURE F-22



EACH TAPE CHANNEL HAS ITS OWN STAR WHEEL AND CARRIER ARM. IF NO HOLES ARE PRESENT IN A PARTICULAR CHANNEL THE STAR WHEEL SLIDES ALONG THE TAPE WITHOUT TURNING. WITH A SERIES OF CONSECUTIVE HOLES, THE STAR WHEEL ROTATES AND THE POINTS DROP INTO EACH SUCCESSIVE HOLE. THE CONTACTS MADE BY THE CARRIER ARMS ARE SWITCHED ONLY WHEN A STAR WHEEL MOVES FROM A HOLE TO A NO-HOLE, OR VICE-VERSA.

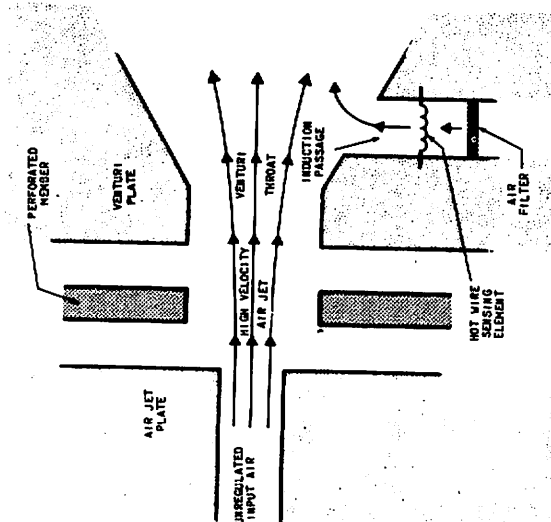
C-6817140-A-1

STAR WHEEL SENSING MECHANISM USED IN TALLY TAPE READERS
FIGURE F-23



SENSING ELEMENT

F-34

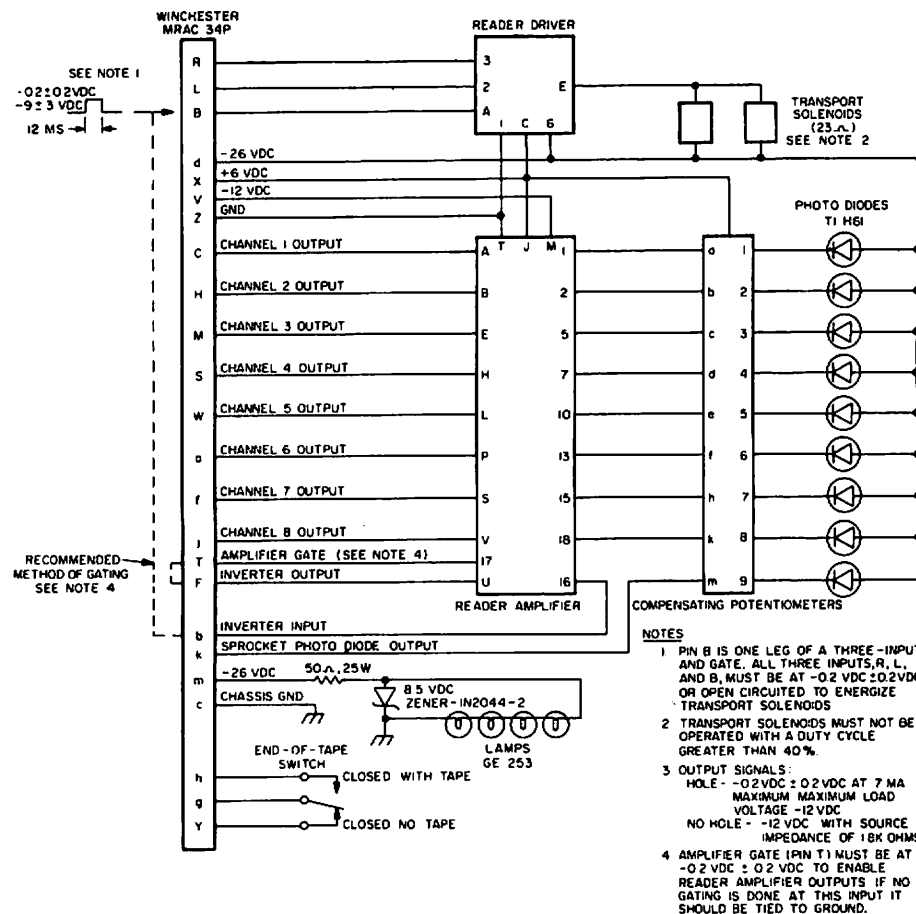


IN THE ANEMOMETER READER, TAPE IS PASSED OVER A READING STATION CONTAINING A FILE OF APERTURES IN CORRESPONDENCE WITH THE HOLE PATTERN OF THE TAPE TO BE SENSED. A POSITIVE PRESSURE AIR SUPPLY IS DELIVERED TO THE APERTURES. AS THE TAPE IS TRANSPORTED ACROSS THE FILE OF APERTURES, THE TAPE ACTS AS A VALVE, PORTING AIR WHENEVER A PERFORATION IS PRESENT AND BLOCKING AIR FLOW WHENEVER THE TAPE IS CONTINUOUS. A CORRESPONDING SERIES OF APERTURES ON THE OPPOSITE SIDE OF A GAP DIRECTS PORTED AIR INTO A VENTURI THROAT. THE VENTURI'S INDUCTION AIR-FLOW DRAWS ADDITIONAL AIR THROUGH AN INDUCTION PASSAGE, THROUGH AN AIR FILTER, AND OVER A HOT-WIRE SENSING ELEMENT WHENEVER THE TAPE PERMITS THE AIR'S ENTRY INTO THE VENTURI. EACH HOT-WIRE SENSING ELEMENT IS WIRED AS ONE LEG OF AN ELECTRICAL BRIDGE CIRCUIT. INDIVIDUAL FEEDBACK AMPLIFIERS ASSOCIATED WITH EACH BRIDGE MAINTAIN THE BRIDGE IN BALANCE. AIR FLOW WHICH WOULD NORMALLY TEND TO COOL THE ELEMENT AND CAUSE BRIDGE UNBALANCE, PRODUCES AN ERROR SIGNAL WHICH PERMITS THE FEEDBACK AMPLIFIER TO ADJUST THE BRIDGE DRIVE SO AS TO RESTORE BALANCE.

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MECHANICS OF SOROBAN HIGH-SPEED TAPE READER

FIGURE F-24

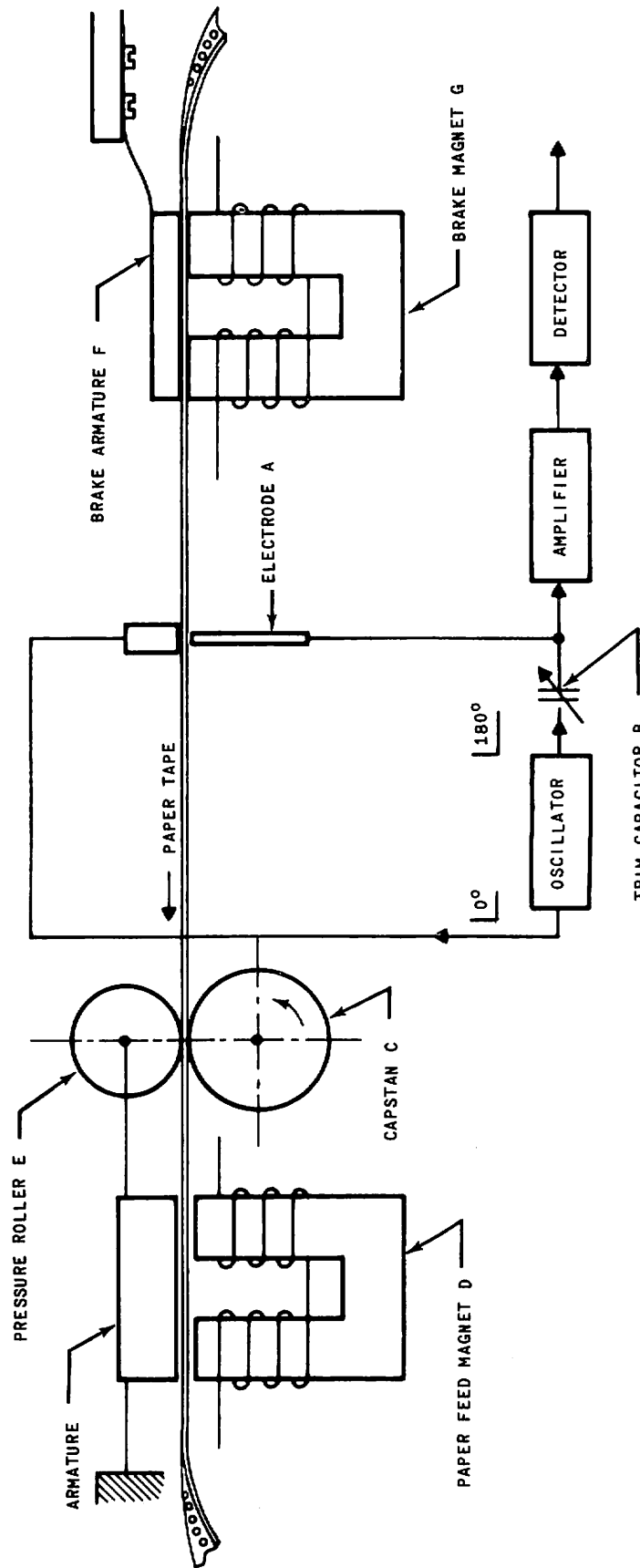


TAPE TRANSPORT FUNCTIONS ARE ACCOMPLISHED BY A DRIVER CIRCUIT AND TWO SOLENOIDS; READ FUNCTIONS ARE PERFORMED PHOTOELECTRICALLY USING A FOUR-LAMP LIGHT SOURCE, A BANK OF NINE PHOTO DIODES (EIGHT FOR DATA AND ONE FOR SPROCKET), AND A DATA OUTPUT AMPLIFIER CIRCUIT. WHEN CONNECTED IN THE SYSTEM ONE PULSE PER CHARACTER IS NEEDED TO OPERATE THE READER AND TRANSPORT THE TAPE. AN INPUT IS PROVIDED TO INHIBIT THE OUTPUT AMPLIFIERS DURING TAPE TRANSPORT. THE SPROCKET HOLE OUTPUT MAY BE USED FOR THIS PURPOSE; HOWEVER, USE OF THE TRANSPORT COMMAND IS RECOMMENDED.

THE READER DRIVER CIRCUIT CONSISTS OF A THREE-INPUT "AND" GATE STAGE, AN EMITTER FOLLOWER STAGE, AND AN INVERTER DRIVER STAGE. THE DRIVER INPUT PINS (R, L AND B) MUST BE IN THE LOGICAL "ONE" STATE ($-0.2 \text{ VDC} \pm 0.2 \text{ VDC}$) OR OPEN CIRCUITED TO ENERGIZE THE TRANSPORT SOLENOIDS. WHEN IN THE LOGICAL "ONE" STATE THE READER DRIVER CIRCUIT APPLIES -26 VDC AT TWO AMPERES TO ENERGIZE THE 23-OHM SOLENOID COILS TO TRANSPORT THE TAPE.

PHOTOELECTRIC SENSING PRINCIPLE AND TAPE HANDLING
TECHNIQUE USED IN INVAC MODEL R-110 TAPE READER
FIGURE F-25

NINE ELECTRODES (A) AND NINE TRIM CAPACITORS (B) (EIGHT CHANNELS PLUS SPROCKET HOLE), ARE POSITIONED AT THE CENTER OF THE TAPE TRANSPORT. AS A CHARACTER BECOMES ALIGNED WITH A ROW OF ELECTRODES, A HOLE IN ANY CHANNEL PRODUCES A CHANGE IN THE READER OUTPUT VOLTAGE. THE OUTPUT PULSES VARY IN LENGTH DEPENDING ON THE TAPE SPEED. THE TAPE IS FED BY A CAPSTAN (C) MOUNTED ON A MOTOR SHAFT. AN ELECTROMAGNET (D) ACTUATES THE PINCH ROLLER (E) WHICH COMES IN CONTACT WITH THE TAPE. THE TAPE IS FED BETWEEN THE BRAKE ARMATURE (F) AND THE BRAKE ELECTROMAGNET (G). TO STOP THE TAPE, THE BRAKE MAGNET ATTRACTS THE BRAKE ARMATURE, THUS PRESSING THE TAPE AGAINST THE TAPE GUIDE PLATE. RAPID BRAKING IS POSSIBLE SINCE MOVABLE PARTS TRAVEL VERY SHORT DISTANCES. READING SPEED CAN BE SET AT 500 OR 1000 CHAR/SEC.



TRIM CAPACITOR B

DIELECTRIC SENSING PRINCIPLE AND TAPE HANDLING TECHNIQUE
USED IN FACIT MODEL PE-1000 TAPE READER

FIGURE F-26

in each row represent one alphabetic character or numerical digit. The maximum number of holes or spots that can be recorded across the tape is referred to as the number of tracks on the tape. The number of tracks used depends upon the type of code used. Present codes use from five to eight tracks.

Paper tape recorders fall into two main categories: coded hole recorders (tape punches) and coded printed spot recorders (electrostatic recorders). Together with magnetic tape transports, electrostatic recording packing density. On the other hand, tape punches are less expensive and record information in a medium more tolerant to severe handling.

3.3.1 Tape Punches. The tape punch or perforator is a device that records information by punching appropriate holes in paper tape. It may be completely self-contained or integrated with other telegraph apparatus. There are several types of tape punches which fall into the following classifications:

(a) Perforator—prepares and stores information on chad or chadless tape, through direct mechanical actions of the keyboard.

(b) Reperforator—this device is a tape perforator with the addition of a receiving-selector mechanism. This addition permits the perforation of a tape from the line signal or from the keyboard.

(c) Typing perforator—this unit is a perforator with the addition of character printing capability. In addition to perforating, it prints the characters on the tape.

(d) Typing reperforator—this device can accept line signals or keyboard information and concurrently perforate and print the character representation on the paper tape.

Figures F-27, F-28, and F-29 show representative types of tape punches.

3.3.2 Electrostatic Recorders. In this class of recorders, an electrostatic charge is applied to the tape surface of a special paper-plastic tape. To make the charged areas visible, the tape is dusted with a special dry ink. Ink particles adhere to the electrostatically charged areas where the particles are fixed by pressure or a combination of heat and pressure. The result is a white tape with black spots corresponding to the perforations found in punched tape. Commercially available models record at speeds as high as 2000 char/sec. Recording speed is limited mostly by the speed capability of the tape drive mechanism. Character packing densities of 20 char/inch and more can be provided.

Electrostatic recorders are essentially electronic devices. They have, therefore, an inherent reliability potential. However, some problems may develop where

inadequate periodic maintenance may be responsible for the printing of gray rather than black spots, thereby decreasing the S/N operating margins of photoelectric readers.

Electrostatic recording is noncompatible in the sense that it cannot be used interchangeably with perforated tape in existing systems. It is, however, compatible to the extent that its spots are similar in size, shape, and location to the holes in punched tape. In terms of optical readout, electrostatic tape is little different from punched tape. Since the electrostatic recorder is basically a type of nonimpact printer, edge printout of characters encoded on the tape can be provided relatively easily and inexpensively. Figure F-30 depicts the basic operating principles of electrostatic tape recorders.

3.4 Printing Techniques

3.4.1 Typebar Printer. Typebar printers are basically electrically powered, manual typewriters with individual linkages for each character. A mechanical encoding mechanism is usually mounted under the keyboard, and is actuated by the typing keys. Decoding is accomplished by a decoding mechanism, also mounted under the machine, which trips individual type bar levers to effect printing. The keyboard is mechanically interlocked to prevent the depression of more than one key at a time. (Refer to Figure F-31.)

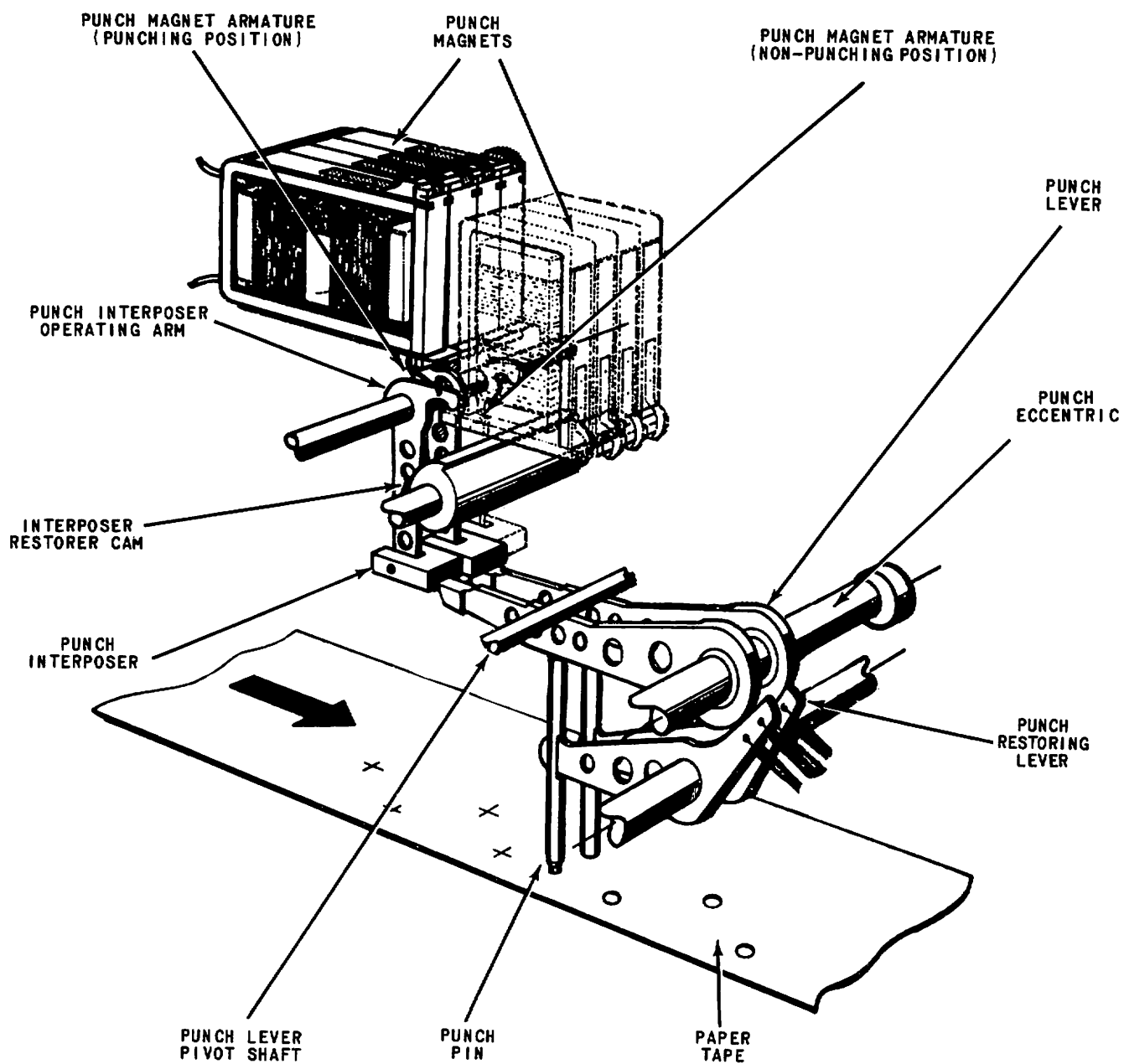
3.4.2 Typebox Printer. The typebox printer is an impact type printer whose functional performance causes a hammer to force the type pallet against the ribbon and paper. The typebox is moved to bring the selected character to the printing position, and after each stroke the typebox is returned to its unoperated position below the printed line. The typebox is easily removable, without tools, for cleaning, interchanging of type, etc. (Refer to Figure F-31.)

3.4.3 Type Cylinder Printer. The type cylinder printer has a number of unique features that allow for reduction in mechanical movement, weight, and size. The machine requires no large bulky roller platen; instead, it has a print hammer that faces the paper against a small type cylinder shown in Figure F-32A and F-32B.

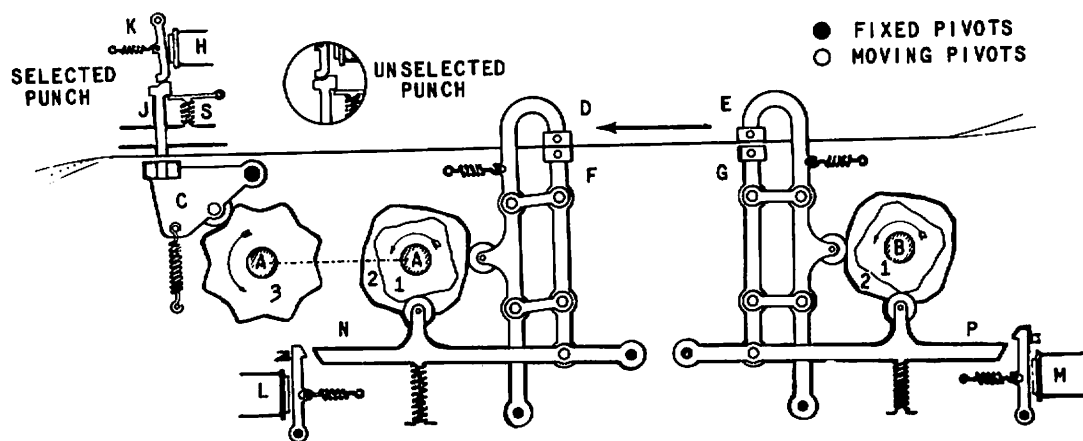
The positioning of the type cylinder is accomplished sequentially on receipt of the 5-unit Baudot code. The positioning mechanism is shown in Figure F-33A.

The combined effects of code units 1 and 2 position the rotary units. The stroke of pulley carriage number 1 is $3/32$ inch and the stroke of pulley carriage number 2 is $3/64$ inch. The stroke of the number 2 pulley is exactly half that of number 1 pulley, so that four evenly spaced rotary positions are possible.

The combined effects of code units 3 to 5 position the lateral units. Here again the stroke for number 4 is



PAPER TAPE PUNCHING MECHANISM
FIGURE F-27



OPERATING SEQUENCE

THE CODE OUTPUT OF THE COMPUTER IS CONNECTED TO A SET OF ELECTROMAGNETS (H) (SEE DIAGRAM) IN THE PUNCH SELECTING UNIT, EACH PAIR OF WIRES OF THE PARALLEL OUTPUT BEING CONNECTED TO A SEPARATE MAGNET. THESE MAGNETS CONTROL THE PUNCHES (J) VIA ARMATURES (K). WHEN A "MARK" SIGNAL IS TRANSMITTED BY THE COMPUTER, THE CORRESPONDING MAGNET IS ENERGIZED, CAUSING ITS ARMATURE (K) TO CAM ITS PUNCH DOWN AND LOCK IT THERE.

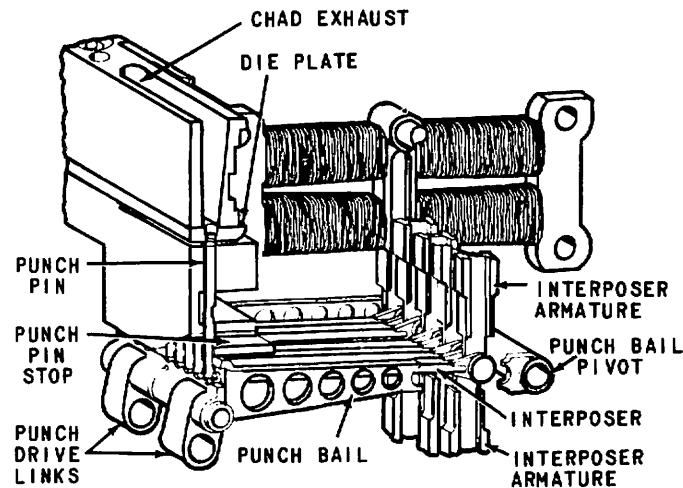
THE FEED SIGNALS FROM THE COMPUTER ARE ARRANGED TO ENERGIZE THE FEED CONTROL MAGNETS (L) AND (M). WHEN THESE MAGNETS OPERATE THEY RELEASE LEVERS (N) AND (P) RESPECTIVELY AND SO PERMIT THE TAPE TO BE FED IN THE MANNER DESCRIBED BELOW.

THE TAPE FEEDING AND PUNCHING ACTIONS ARE PERFORMED BY A MOTOR-DRIVEN PUNCH AND FEED UNIT. THIS CONTAINS TWO CAM ASSEMBLIES (A) AND (B) WHICH, WHEN THE POWER TO THE TAPE PUNCH IS SWITCHED ON, CONTINUOUSLY ROTATE AT THE SAME SPEED IN AN ANTI-CLOCKWISE DIRECTION.

FOUR OF THE CAMS IN THESE ASSEMBLIES (I.E., A1, A2, B1 AND B2) CONTROL THE MOVEMENTS OF THE TAPE FEED FRAMES (D) AND (E) AND CLAMPS (F) AND (G). AS THE CAM SHAFTS ROTATE, THE FRAMES OSCILLATE IN OPPOSITION TO EACH OTHER AND THE CLAMPS RISE TO GRIP THE PAPER ALTERNATELY AT SUCH TIMES THAT THE FRAMES ARE MADE TO FEED THE TAPE FORWARD IN A STEP-BY-STEP MANNER A DISTANCE OF 1/10-IN. AT A TIME. THE REMAINING CAM (A3) CAUSES THE DIE-PLATE (C) TO RISE AND LIFT THE PAPER AGAINST THE SELECTED PUNCHES, THEREBY PERFORATING IT.

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ELECTROMECHANICAL PUNCHING PRINCIPLE AND TAPE HANDLING
TECHNIQUE USED IN CREED MODEL 3000 PAPER TAPE PUNCH
FIGURE F-28



PUNCH BAIL AND INTERPOSERS

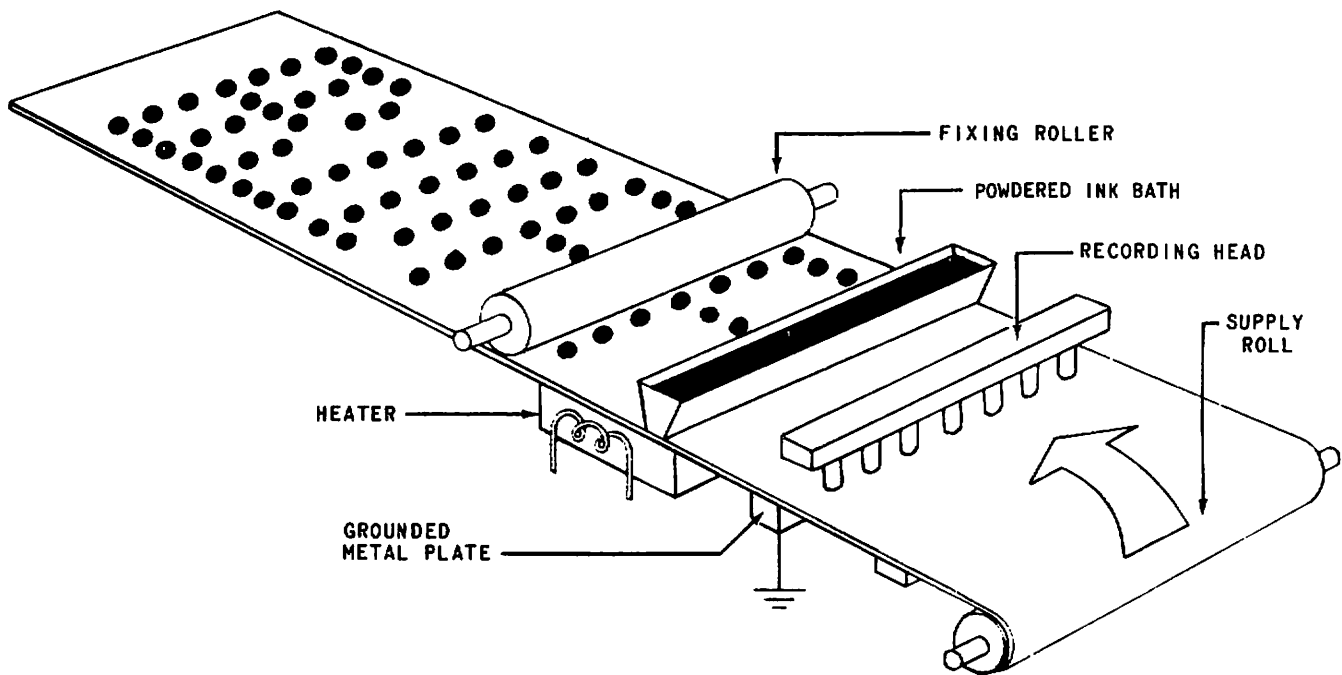
THE PUNCH BAIL CONTAINS A PUNCH PIN INTERPOSER FOR EACH DATA CODE LEVEL PLUS ONE FOR THE SPROCKET HOLE. THE PUNCH BAIL IS STATIONARY FOR ONE-THIRD OF EACH PUNCH CYCLE.

DURING THE PERIOD WHEN THE PUNCH BAIL IS STATIONARY, THE SELECTED CODE MARK MAGNETS MUST BE ENERGIZED TO INSERT INTERPOSERS BETWEEN THE BAIL AND PUNCH PINS. DURING THE UPWARD DRIVE PERIOD, THE BAIL DRIVES THE SELECTED PUNCH PINS THROUGH THE TAPE AND INTO THE DIE BLOCK. ON THE BAIL RETURN STROKE, DRIVE MUST BE REMOVED FROM THE MARK MAGNETS AND THE CODE SPACE MAGNETS MUST BE ENERGIZED TO WITHDRAW THE INTERPOSERS. THE BAIL CONTINUES DOWNWARD AND POSITIVE WITHDRAWAL OF THE PUNCH PINS IS ACCOMPLISHED BY THE ENGAGEMENT OF THE BAIL'S EDGE WITH THE FLAT NOTCH GROUNDED IN THE PUNCH PINS. THE PUNCH PIN STROKE IS APPROXIMATELY 0.032 INCH, OF WHICH 0.013 IS FOR PENETRATION OF THE PUNCH PINS INTO THE DIE PLATE AND 0.010 IS FOR WITHDRAWAL INTO THE GUIDE BLOCK FOR STRIPPING.

(Used with permission of copyright owner.)

**BASIC PUNCHING UNIT FOR SOROBAN MODEL GP-2 PERFORATOR
FIGURE F-29**

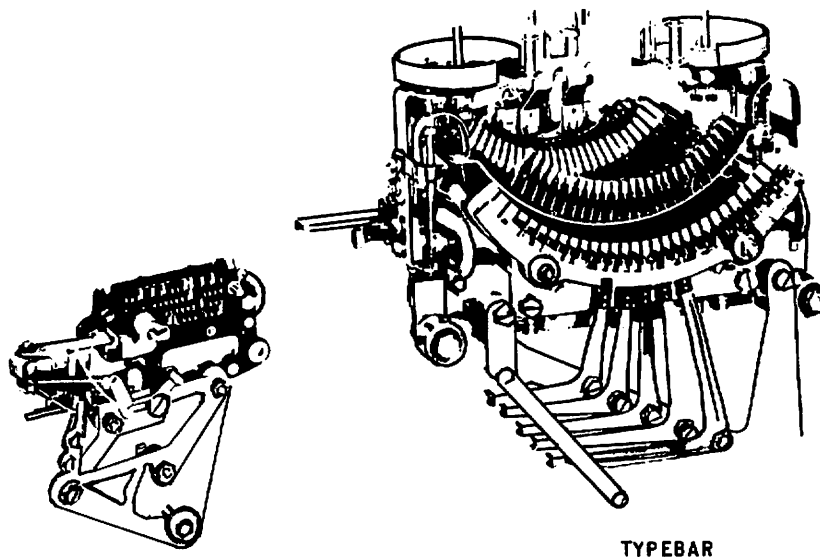
A HIGH-RESISTIVITY PLASTIC-COATED PAPER TAPE WITH A CONDUCTIVE BACKING IS PASSED THROUGH THE "WRITING" HEAD, WHICH CONSISTS OF TWO SETS OF CLOSELY-SPACED ELECTRODES. PULSING THE ELECTRODES LEAVES AN ELECTROSTATIC CHARGE ON THE SURFACE OF THE TAPE. THE TAPE IS THEN PASSED THROUGH DRY POWDERED INK WHICH ADHERES TO THE CHARGED AREAS IN TINY CAPSULE-SHAPED SPOTS. THESE SPOTS ARE THEN PERMANENTLY FIXED.



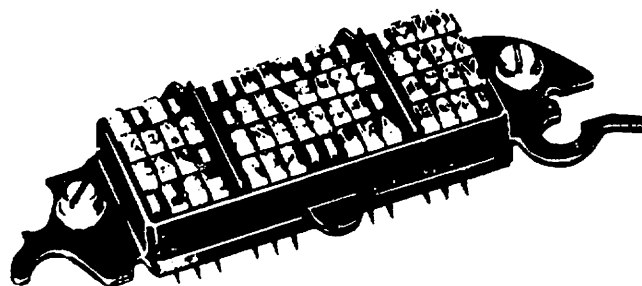
SEQUENCE OF OPERATION

1. THE PAPER IS FED UNDER A RECORDING HEAD AND OVER A GROUNDED METAL PLATE. THE RECORDING HEAD CONSISTS OF SEVEN IN-LINE ELECTRODES. ALL ALPHABETIC AND NUMERICAL CHARACTERS CAN BE FORMED BY PULSING THE PROPER COMBINATION OF ELECTRODES. AS AN ELECTRODE IS PULSED, A FLOW OF ELECTRONS TO THE GROUNDED METAL PLATE DEPOSITS AN ELECTROSTATIC CHARGE IN A SPECIFIC SPOT ON THE PAPER. THERE IS NO CONTACT BETWEEN THE PAPER AND THE PIN ELECTRODES.
2. THE PAPER PASSES THROUGH A BATH OF DRY INK PARTICLES WHICH ADHERE TO THE PAPER ONLY ON THE SPOTS WHICH CARRY AN ELECTROSTATIC CHARGE.
3. A COMBINATION OF HEAT AND PRESSURE PERMANENTLY FIXES THE INK TO THE PAPER. THE FINISHED PRODUCT WILL NEITHER SMEAR NOR FADE.

BASIC OPERATING PRINCIPLES OF ELECTROSTATIC TAPE RECORDERS
FIGURE F-30



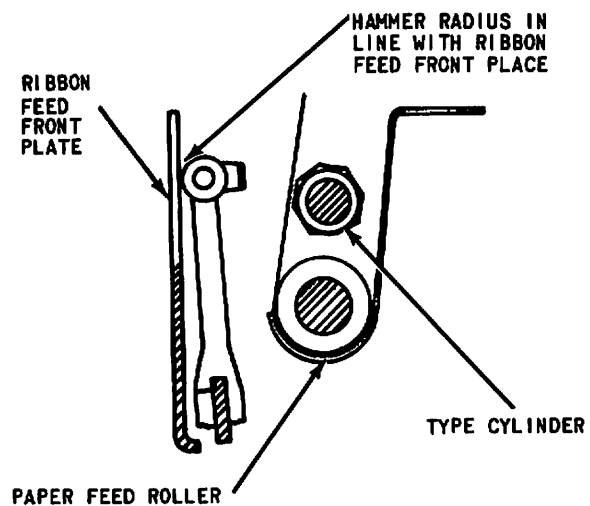
SIZE OF CARRIAGE SHOWN IN RELATION TO
CONVENTIONAL "BASKET" CARRIAGE



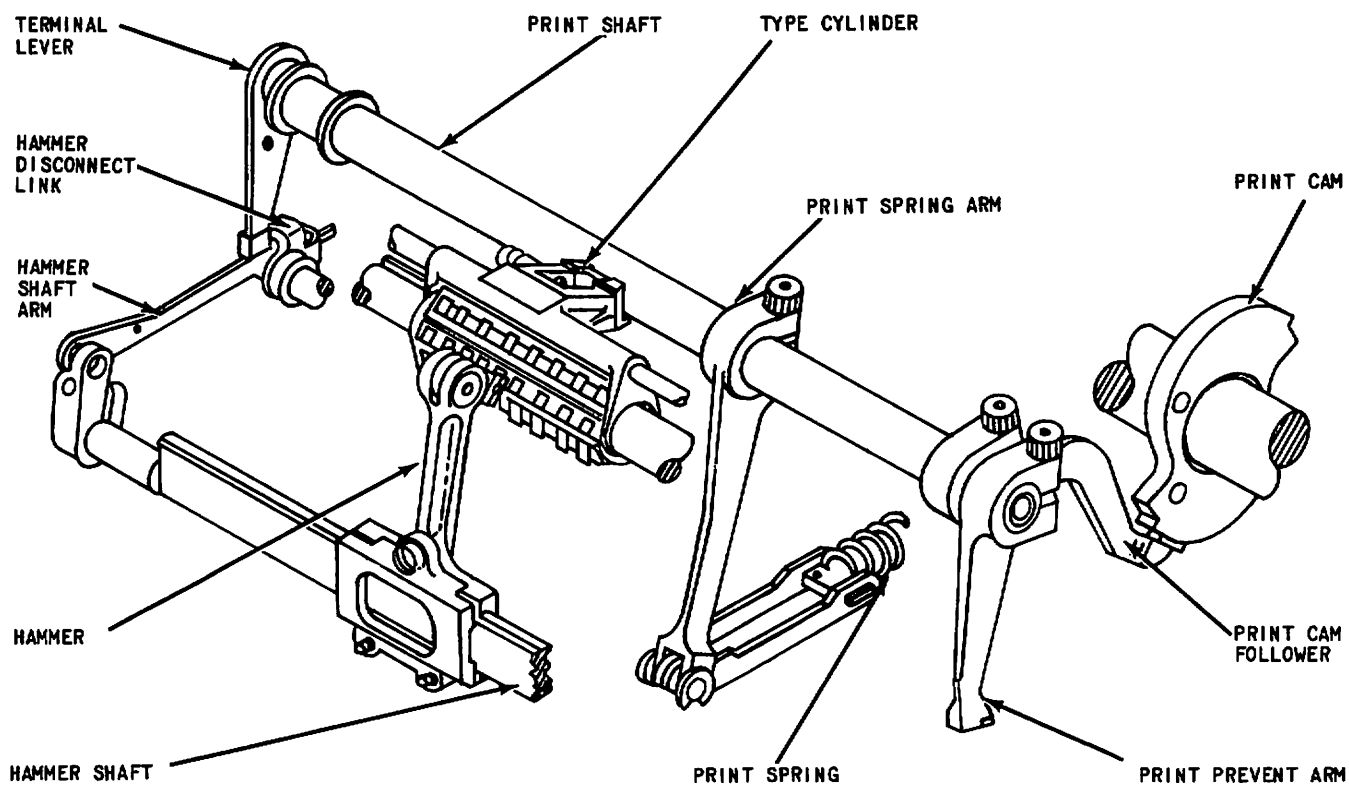
THE TYPEBOX
ACTUAL SIZE

HOW THIS PRINTING PRINCIPLE WORKS: (A) THE TYPEBOX IS MOVED TO BRING THE SELECTED CHARACTER TO THE PRINTING POSITION; (B) THE PRINT HAMMER DRIVES THE TYPE PALLET AGAINST THE RIBBON AND PAPER. AFTER EACH STROKE THE TYPEBOX IS RETURNED TO ITS UNOPERATED POSITION BELOW THE PRINTED LINE. SHIFT AND UNSHIFT ARE GOVERNED BY TYPEBOX POSITION; THE PLATEN REMAINS STATIONARY.

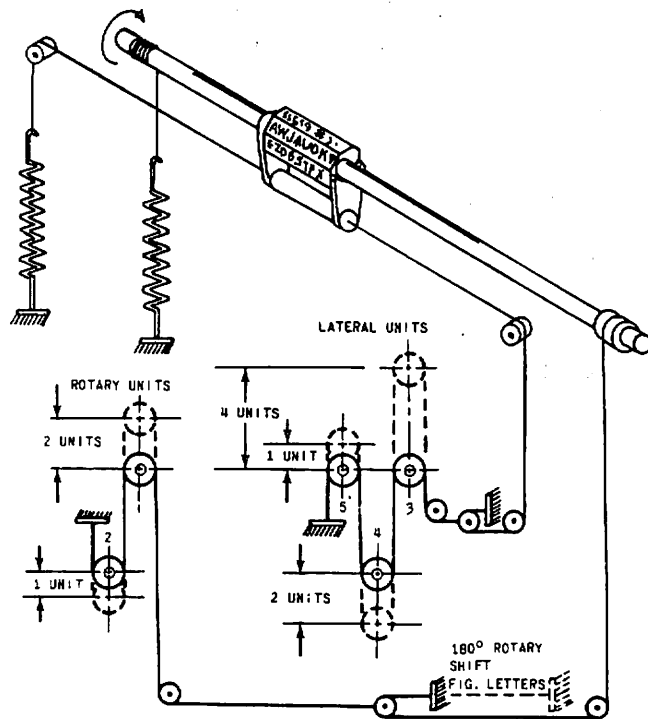
(Used with permission of copyright owner.)
TYPEBAR AND TYPEBOX PRINTER
FIGURE F-31



HAMMER BACKSTROKE ADJUSTMENT
FIGURE F-32A



FUNCTION SELECTOR, CHARACTER PRINTING LINKAGE
FIGURE F-32B



TYPE CYLINDER POSITIONING MECHANISM
FIGURE F-33A

PAGE PRINTER										
DEVELOPED PRINT CYLINDER										
LETTERS-FIGURES CAM HIGH SIDE	1	2	A	W	J	A	U	Q	K	W
	1		E	Z	D	B	S	Y	F	X
	2		≡	L	R	G	I	P	C	V
			≡	T	<	0	■	H	N	M
LETTERS-FIGURES CAM LOW SIDE	1	2	—	2	'	▲	7	1	(	W
	1		3	"	\$	?	⊙	6	l	/
	2		≡	)	4	&	8	0	:	;
			≡	5	<	9	■	#	,	.
CAMS ON HIGH SIDE			3	3	3	3				
			4	4			4	4		
			5		5		5		5	

TYPE CYLINDER CHARACTER ARRANGEMENT
FIGURE F-33B

twice that of number 5, and the stroke for number 3 is twice that of number 4; therefore, eight lateral positions are possible.

The developed view of the type cylinder (Figure F-33B) shows the eight vertical (rotary) type cylinder positions. Four of the eight rotary positions correspond to letters; the other four correspond to figures. The letters-figures pulley system determines within which group of four rows the subsequent rotary positioning will take place. The stroke of the pulley, through which the rotary cable passes, positions the type cylinder so that the subsequent selection will be within one of the two 180-degree segments of the cylinder.

3.4.4 Drum Printer. This type of machine is used for high-speed data up to 400 words per minute. Unlike mechanical typebar, type box, and type cylinder printers, this type of printer has no mechanical linkage between keyboard and printer. Encoding is accomplished with a linkage arrangement within the keyboard, which closes from one to six switches (for each key depression), thus generating the binary code. The printing mechanism is a continuously rotating print drum, and one or two solenoid-actuated print hammers that are stepped from left to right. The printer-hammer carrier pauses to allow the hammer to strike the ribbon against the paper as the desired character passes under the paper at the printing point. Decoding for the selection of character to be printed is accomplished electronically by detecting coincidence between a code indicating the rotated position of the drum and the code of the incoming character. (Refer to Figure F-34.)

3.4.5 Optical Printers. Optical printing methods used in high-speed line printers apply principles whereby master characters are illuminated as required and their images are optically projected onto a moving photographic-type recording medium. As in the case of "Xerography," the image projected onto a rotating drum causes electrostatic images to form on the drum. This electrostatic image is made visible by the application of a black thermoplastic type powder to the drum surface, adherence occurring only where electrostatic images have been formed. The powder image is transferred to paper where it is affixed by the application of heat. (Refer to Figure F-35.)

3.4.6 Electrographic and Electrostatic Recording Principles. In electrographic printing, alphanumeric characters are by electrical pulses fed to printing styli in contact with a dry burn-off type facsimile paper. The paper is a highly conductive, carbon-loaded electro-marking paper possessing a thin-mark coating of white semiconducting material. The application of a pulse to a stylus creates a black dot at the point of contact with

the paper by destroying the white material. (Refer to Figure F-36.)

In electrostatic printing, the paper is fed under a recording head consisting of in-line pin electrodes. All alphanumeric characters are formed by pulsing the proper combination of electrodes, depositing electrostatic charges in specific areas on the paper. The paper passes through a bath of dry ink particles that adhere to the paper only in those areas that are electrostatically charged. A combination of heat and pressure permanently fixes the ink to the paper. This is similar in techniques to that shown in Figure F-30.

3.5 Printer Packages.

The configurations that follow are the results of combining units previously described in varying arrangements for operational utility or convenience.

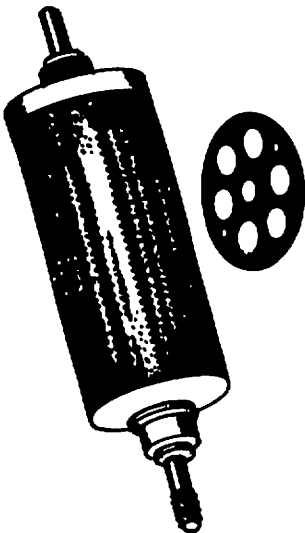
3.5.1 Input/Output Printers. Unlike output printers, input/output (I/O) printers are equipped with a keyboard for local data input. The use of these devices, in conjunction with some form of tape recorder, makes it possible to generate a recording machine-language medium as a by-product of the typing of a document. This combination of document preparation, at the same time as the creation of a recording machine-language medium record, eliminates a separate key-punching operation for data or eliminates a separate teleprinter keyboard operation for messages. Such procedures provide marked reductions in the cost of preparing information for entry into a communication system and reduce human errors in keyboard manipulation. When combined with a tape reader, I/O printers are used as output printers capable of printing at a maximum data rate of 10 to 40 char/sec. The maximum effective input rate is 10 to 15.5 char/sec for machines available today.

3.5.2 Send/Receive and Receive Only Page Printers. The send-receive (S/R) page printer or teletypewriter is a device capable of sending and receiving printed messages over telegraph lines. By means of the keyboard, the page printer converts the keyed information onto sequential electrical signals which can be transmitted over a pair of wires. A hard copy of the message is produced at the sending and receiving station simultaneously.

The receive-only (R/O) page printer functions in the same manner as the S/R page printer, with the limitation that it is only capable of receiving messages. The R/O unit converts the electrical sequential pulses into a printed page. It is basically the same machine as the S/R page printer, with the exception of the keyboard and transmitting equipment.

TYPE DRUM

THE TYPE DRUM IS ARRANGED FOR A PRINT LINE OF 72, 76 OR 80 CHARACTERS, SPACED 10 CHARACTERS PER HORIZONTAL INCH. PAPER FEEDING IS 6 CHARACTERS PER VERTICAL INCH. THE DRUM CONSISTS OF 36, 38 OR 40 TYPEWHEELS JOINED TOGETHER ON A COMMON SHAFT. A TYPEWHEEL HAS TWO ROWS OF CHARACTERS, EACH ROW CONSISTING OF 64 CHARACTERS. THE CHARACTERS ARE ARRANGED AROUND THE PERIPHERY OF THE TYPEWHEEL IN THE ORDER OF THEIR BINARY CODE. THE DRUM ROTATES AT A FIXED SPEED. IT IS NOT NECESSARY TO CHANGE THE SPEED OF THE DRUM TO ACCOMMODATE DIFFERENT PRINTING RATES. STANDARD TYPEDRUMS INCLUDE GRAPHICS FOR STANDARD COMMUNICATIONS, INTERNATIONAL COMMUNICATIONS, WEATHER, FRACTIONS AND DATA.



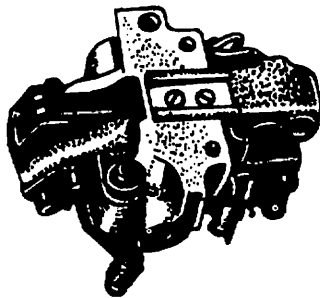
TYPE DRUM

PRINT HAMMER

SINGLE AND DOUBLE PRINT HAMMER MODULES ARE AVAILABLE. THE CHOICE OF HAMMER MODULE IS DETERMINED BY PRINTING RATE REQUIREMENTS.

A SINGLE HAMMER MODULE PROVIDES FOR PRINTING RATES UP TO 200 WORDS PER MINUTE AND PRINTING RATES OF 400 WORDS PER MINUTE ARE ATTAINED WITH THE DOUBLE HAMMER MODULE.

PRINTING IS ACCOMPLISHED BY STRIKING THE HAMMER AGAINST RIBBON, PAPER AND TYPEDRUM AS THE DESIRED CHARACTER PASSES.

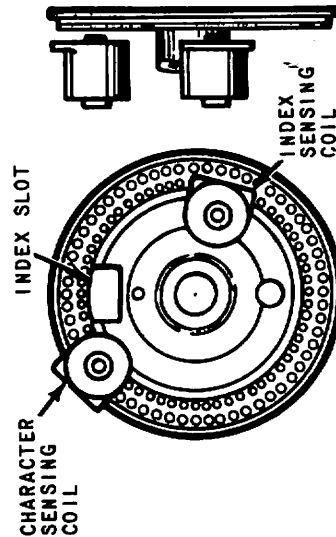


PRINT HAMMER (DOUBLE)

F-46

DRUM CLOCKING WHEEL

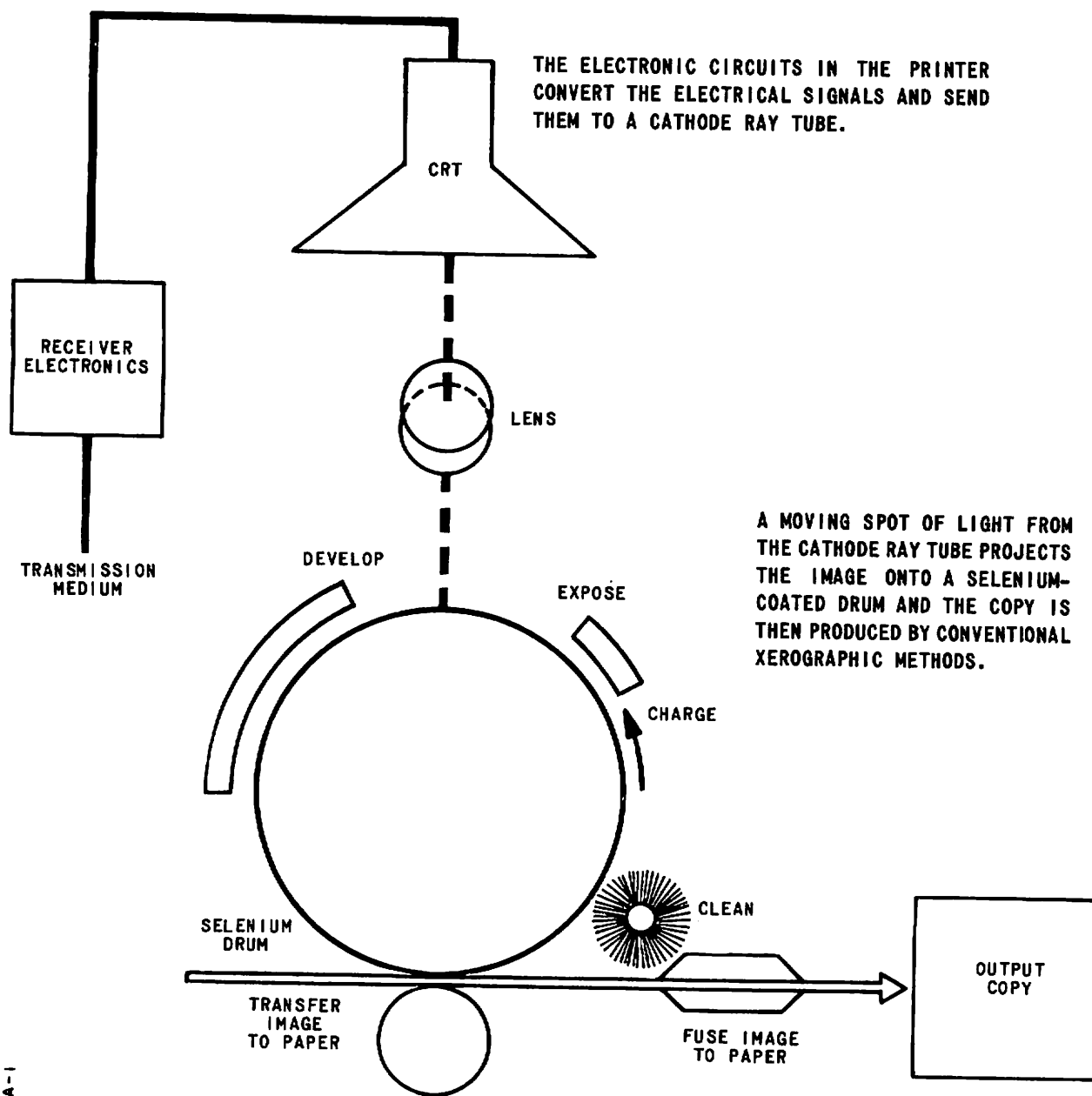
THE CLOCKING WHEEL IS A DIECAST ALUMINUM DISC CONTAINING 64 PERFORATIONS AND AN INDEX SLOT. THE INDEX SLOT IS LOCATED ON THE INNER PERIPHERY OF THE WHEEL. THE CLOCKING DISC IS MOUNTED TO THE TYPEDRUM SHAFT AND REVOLVES WITH THE TYPEDRUM. THE ROTATION OF THE CLOCK WHEEL IS MONITORED BY TWO COILS USED TO CONTROL THE ELECTRONIC COUNTER. ONE COIL IS USED FOR CHARACTER SENSING AND ONE FOR INDEXING. THE CHARACTER SENSING COIL MONITORS THE 64 PERFORATIONS IN THE CLOCK WHEEL, PROVIDING VOLTAGE PULSES TO STEP THE ELECTRONIC BINARY COUNTER THROUGH ITS 0 TO 63 POSITIONS. THE INDEX SENSING COIL MONITORS THE INDEX SLOT AND PROVIDES A VOLTAGE PULSE TO ASSURE THAT THE BINARY COUNTER IS RESET TO ZERO ONCE PER REVOLUTION. ELECTRONIC DETECTOR REGISTERS ARE PROVIDED FOR THE USUAL MACHINE FUNCTIONS SUCH AS LINE FEED, CARRIAGE RETURN, SPACE, ETC. THE DRUM CLOCKING WHEEL SYNCHRONIZES THE DRUM CHARACTER POSITION WITH THE ELECTRONIC CIRCUITRY.



DRUM CLOCKING WHEEL

DRUM PRINTER USED IN ELECTRONIC DATA PRINTERS FOR KLEINSCHMIDT MODELS

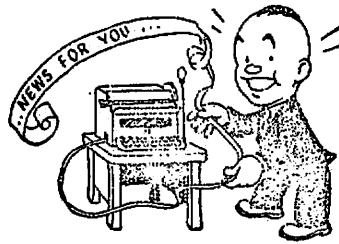
FIGURE F-34



C-6817045-A-1

ELECTROSTATIC METHOD OF PRINTING
FIGURE F-35

PART G
MESSAGE CENTERS



Part G

Message Centers

1.0 TELEGRAPH CENTRAL OFFICE EQUIPMENT

The telegraph central office is the central point which, for its particular area, directs and regulates the movement of telegraph messages. From such points, the operating personnel also maintain constant supervision over the proper functioning and needed repairs to equipment and outside plant.

The principal classification of central office equipment may include:

(a) Terminal equipment for open-wire and cable lines (entrance cables, main distributing frames, protectors, and test boards). The Main Distributing Frame (MDF) is a metal framework supporting the pair-by-pair termination of the entrance cables through which the outside plant wire and cable lines extend into the central office. Protector mountings are provided for each cable pair consisting of heat coils (fuses) and carbon block discharge gaps. The protectors will function to prevent excessive foreign currents (or voltages) from damaging the central office cables and equipment.

(b) Intermediate operating equipment (intermediate distributing frames, repeaters, telegraph carrier terminals, and reperforator switching equipments). The Intermediate Distributing Frame (IDF) frames have terminal blocks mounted on their two sides, to which the various equipment units in the office are wired. Office cables extend from these frames to testboards, telegraph operating positions, teletypewriter switchboards, and to the main frame. By cross-connections on these frames, incoming circuits may be connected to various testboards and switchboard jacks, operating positions, and equipment units as desired.

(c) Operating positions. Teletypewriter switchboard, operating positions for Morse, and teletypewriter sending and receiving apparatus, tape perforators, reperforators, and transmitter-distributors, as well as telephone switching facilities.

(d) Power equipment. Power generating equipment, e.g., rectifiers and motor generators, power switchboards, power-distributing systems to power operated units, storage batteries, and emergency power plants.

(e) Building equipment. Lighting, heating, ventilation, and personnel quarters.

2.0 TELEGRAPH SWITCHING

In military systems there are two basic forms of telegraph switching, message switching and circuit switching. In message switching, switchboards are not used, and the messages are transferred from one circuit to the next in the form of perforated tape.

In circuit switching, the circuits are connected together at switchboards, as in telephone switching. Circuit switching is generally used for local manual teletypewriter circuits, which do not send or receive a sufficient number of messages to justify being tributary stations on the tape relay network.

Because the teletypewriter enables a message to be telegraphed by an operator who needs only to be a competent typist, a teleprinter exchange (TELEX) system is in general use by business firms. Teletypewriter subscribers can be connected to the commercial telephone exchange through a voice frequency converter so that the subscriber can telegraph over the telephone system to any other subscriber having the same TELEX equipment.

3.0 MESSAGE-SWITCHING CENTERS

3.1 General

Large military communication centers, which require message-switching capabilities, use the store-and-forward technique. Message switching, involving store-and-forward methods, is a delayed type of switching. This method is opposed to circuit switching, which is a real-time operation, and is generally used in voice-switching telephone networks.

These message-switching centers, sometimes called tape-relay stations, require typing reperforators for recording incoming messages and transmitter-distributors for transmitting outgoing messages.

The principal classes of message-switching centers are manual (torn tape), semiautomatic, and fully automatic centers.

Torn-tape centers require considerable manpower and can incur major traffic delays. Torn-tape working becomes difficult in a large center; hence, a variety of automated tape centers have been developed. The automatic tape centers introduced a major improvement in service and a reduction in manpower. A major feature is routing line segregation, which is the ability of the switching center to automatically separate the multiple address incoming messages and direct them to the correct outgoing lines. However, the automatic systems had serial storage problems and difficulties of access to priority messages back in the tape. In the large automatic centers, the tape machinery is subject to significant wear in this heavy-duty environment. Also, since the cross-office speed is only slightly in excess of line speed, queuing problems arise.

Recent developments use electronic storage to eliminate mechanical wear and improve grade of service. With its freedom of access, electronic storage is similar to the torn-tape office in that message-storage and cross-office handling is parallel, i.e., any tape may be drawn from in-transit storage and dealt with, regardless of its chronological order of arrival. This gives great freedom for manipulation of precedence sequencing, etc. It also permits very high cross-office speed, thereby eliminating interval queuing and improving the minimum reaction time.

3.2 Manual Relay (Torn Tape)

The manual store-and-forward message relay (torn tape) center comprises a large percentage of the existing teletype relays in military communications. Single or multiple address messages in 5-unit International Number 2 Teleprinter Code are processed by these centers. The quantity of incoming and outgoing line units is readily increased by addition of standard modules of appropriate type. Each incoming or outgoing line unit can be arranged to operate at one of three speeds (60, 75, or 100 wpm). The speed change for message transmission is effected by the separation of these units.

In some switching centers, all messages are automatically duplicated, dated (in some cases, timed), and held in storage. In some cases, attendants correct errors in routing indicators or in the literal text before relaying onward. All tapes for relaying are temporarily stored, first within priority groups, and then on a first-come, first-served basis. When a message has preemptive ability, it is brought to the outgoing line immediately. At the discretion of the attendants, the preemptive message

interrupts the message being transmitted, or is sent immediately thereafter.

The manual center is divided into five basic units: incoming line unit (ILU), tape multiplication unit, cross-office area, outgoing line unit (OLU), and intercept position. A monitor position may or may not be included.

The ILU is usually a typing reperforator that transforms electrical signals into punched paper tape form; a number of these machines are served by one operator. No action can be taken on a message until it is completely received. At that time, the tape is torn from the ILU (hence the term torn tape), and carried to the cross-office area. However, if the message has multiple routing indicators, it is forwarded to the tape multiplication unit instead.

The cross-office area in a manual center consists of some type of storage from which the message can be transferred to the OLU. Such a device is often called a washboard. A tape is placed in a slot corresponding to its destination and within a particular precedence category. The tape is pulled by an operator on the outgoing side of the cross-office unit and inserted in the OLU. The tapes in the cross-office unit are served within priority groups on a first-come, first-served basis.

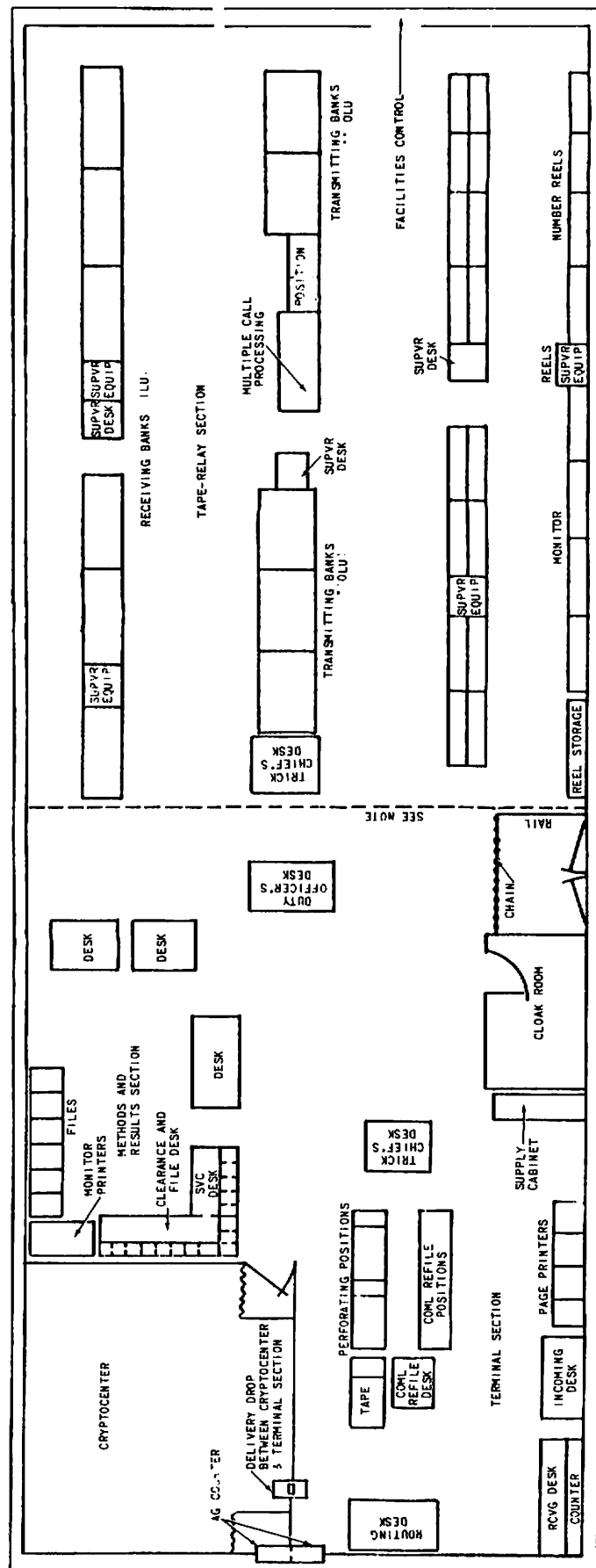
If the message has several routing indicators, the tape must be carried to a tape multiplication unit. This device is essentially one distributor transmitter and a number of reperforators in parallel. When the additional tapes are produced, each tape is placed in its corresponding destination slot on the cross-office unit. These are then treated as individual single address messages.

The OLU consists of distributor-transmitters, sometimes with page printers and often with typing reperforators for monitoring and message accounting. Where equipment is available, two transmitters may be connected to one outgoing line and operated alternately for improved efficiency.

Various errors will occur, e.g., invalid routing indicator, improper message format, or improper machine functions. Messages with errors are carried to the intercept position prior to any tape multiplication or cross-office handling. Although relatively few messages contain errors, the delays resulting from the intercept operation are significant. Corrected messages from the intercept position are refiled on a special ILU. From that point, the message is transferred cross office or the necessary additional tapes are prepared. Figures G-1 and G-2 show typical manual tape relay station operation rooms.

3.3 Semiautomatic Store-and-Forward Switching

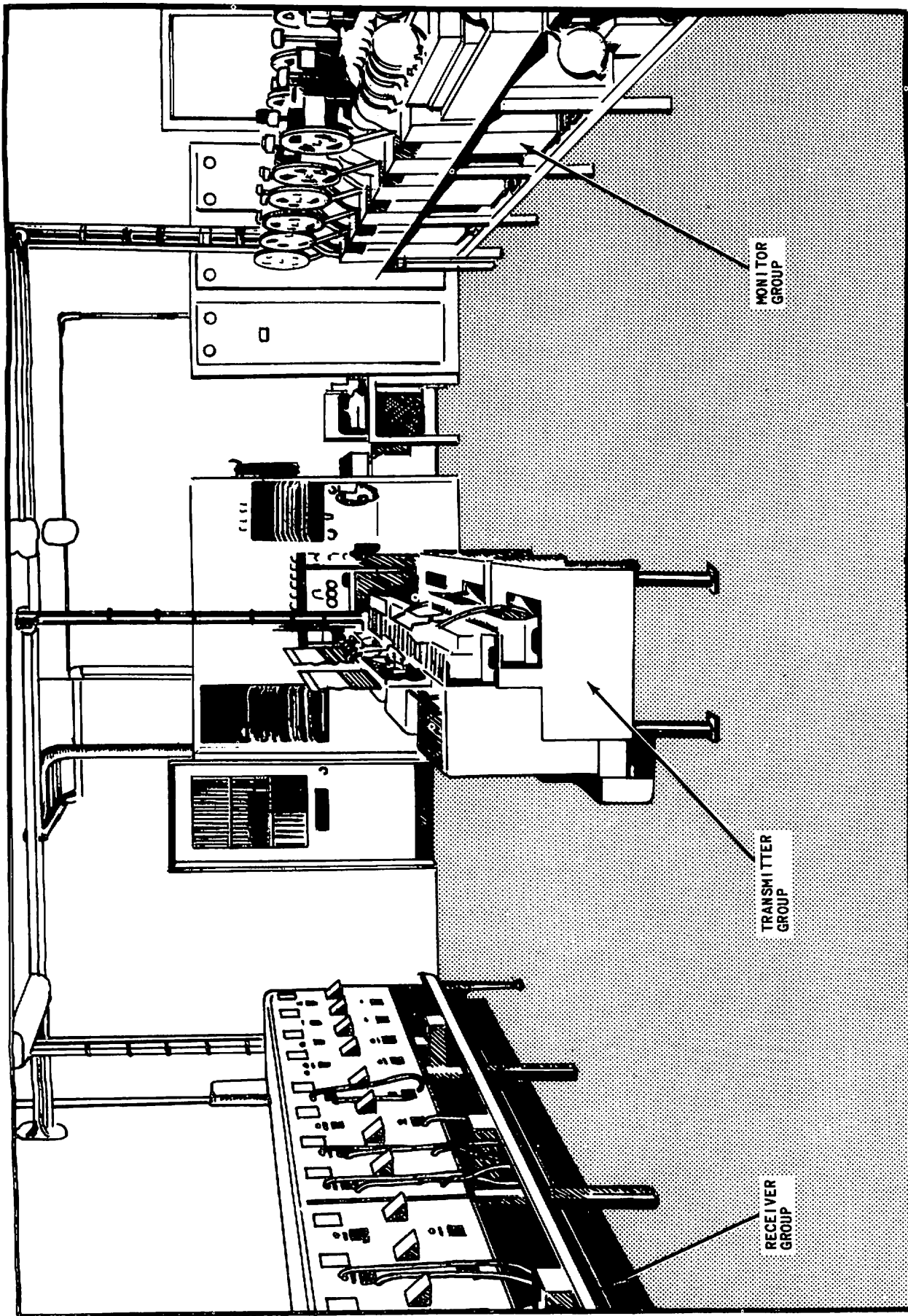
Limited use has been made of semiautomatic tape relay centers. This section describes the essential fea-



NOTE: TERMINAL SECTION AND TAPE-RELAY SECTION MAY BE LOCATED IN SEPARATE ROOMS OR BUILDINGS.

* ILU - INCOMING LINE UNIT.
 ** OLU - OUTGOING LINE UNIT.

COMBINED MANUAL TAPE RELAY AND TERMINAL SECTIONS
 FIGURE G-1



MANUAL TAPE RELAY STATION OPERATIONS ROOM
FIGURE G-2

tures of the military centers operating in this mode and utilizing Western Union Plan 51 equipment. The only other known semiautomatic equipment is an electronic vacuum tube design operating in England which, although superior to Plan 51, is not described herein. In view of automatic electronic development, there appears to be little future for a semiautomatic device.

The Plan 51 is a semiautomatic message switching center, handling single and multiple address messages in 5-unit International Number 2 Teleprinter code in ACP 127 format. This center consists primarily of self-contained incoming units with pushbutton control for selecting the outgoing circuits. The proper connection through the center is established by the attendant, manually translating the routing indicator to an outgoing line designation. The start of message symbol and end of message symbol are automatically alarmed to alert the attendant. Routing indicators and channel designation serial numbers must be visually inspected for each incoming message. At this position the attendant will select the outgoing lines and transmit the message. If an error occurs in the routing indicator portion of the tape, the message is sent to an operator service position where the tape is corrected and reintroduced into the system. If there are errors in the literal text, these are corrected as well. An incoming message having a preemptive requirement is given preferential treatment, but no outgoing messages are cancelled in its favor.

Each incoming unit contains two typing reperforators with associated transmitter-distributors for serving two incoming lines. The pushbutton selector panel with associated alarm circuitry requires an attendant to perform each function. The channel designation serial number is visually inspected and the proper outgoing line is selected after translating the routing indicators. The message is transmitted cross-office at 75 wpm to another reperforator and transmitter-distributor, which is associated with the line. If the message has multiple routing indicators, it is routed to the master sending position, which may select more than one cross-office line. Incoming and outgoing message speed is 60 wpm.

3.4 Automatic Store-and-Forward Switching

A number of automatic tape relay centers have been developed. The characteristics of the three main military systems are outlined in this section. The AN/FGC-30A is a message-switching system used by the U.S. Army for its common user teletype network. The 82-B-1 is a system used by the Navy for its common user teletype network connecting the automatic relay centers. The Plan 55 is automatic message-switching equipment used by the U.S. Air Force in a network of key Air Force centers located in various parts of the world. Other forms are

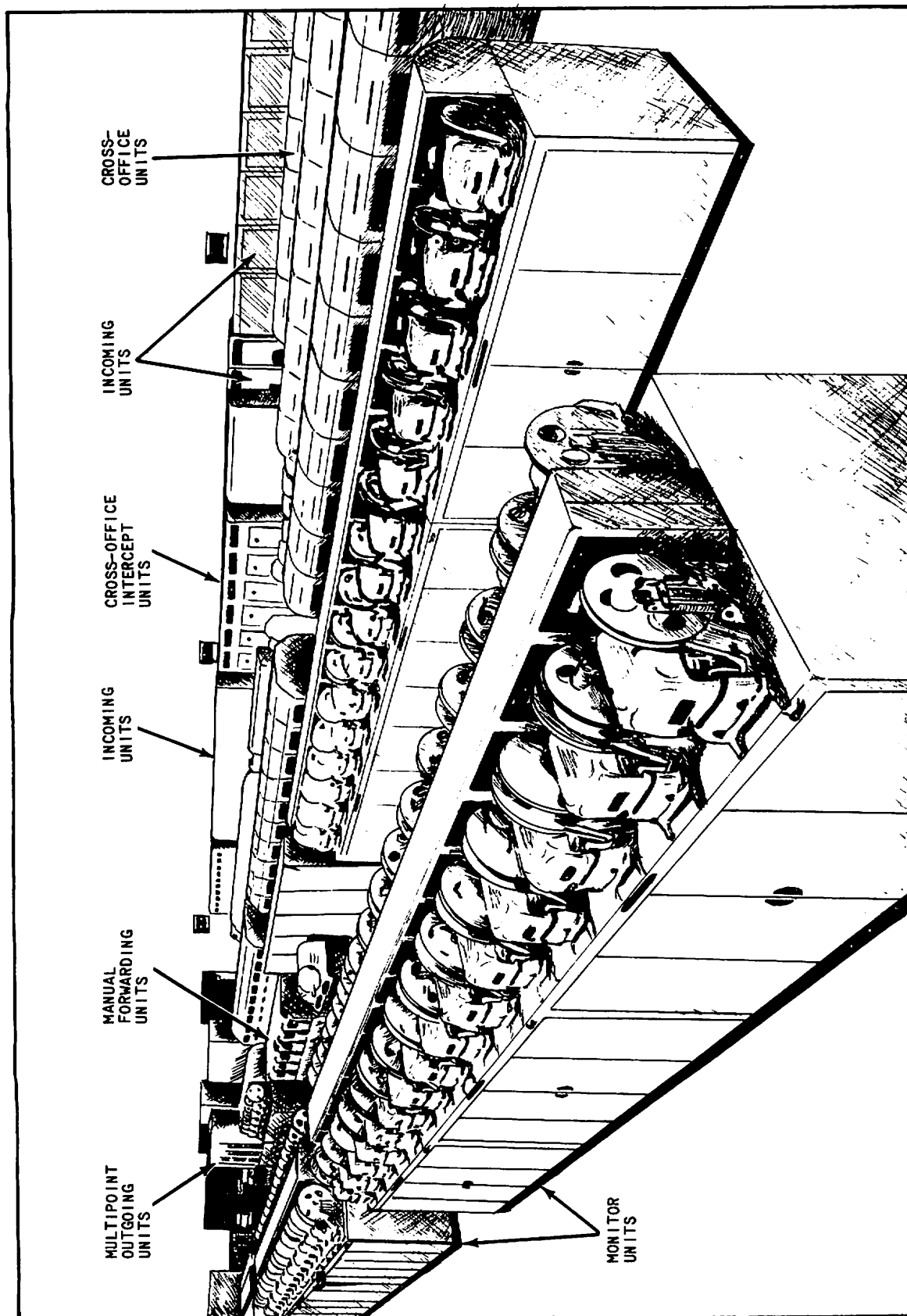
in use but the trend is to supersede these tape centers by electronic centers. Figure G-3 shows an operations room, automatic message-switching tape relay station.

3.4.1 Automatic Relay Center (AN/FGC-30A). The AN/FGC-30A is designed to operate as a fully automatic message-switching center (Figure G-4); under emergency conditions, it can continue to function as a manual (torn-tape) center. Single and multiple address messages in the 5-unit International Number 2 Teleprinter code in ACP 127 format (Communication Instructions Tape Relay Procedures) are received by the center at speeds of either 60 or 100 wpm. All incoming channels are connected to an incoming line unit (ILU) where circuit access jacks allow monitoring and patching when required. The number of incoming line units, each serving two lines, is readily changed by the addition or removal of standard modules. A group of 13 ILU's (25 incoming lines plus 1 spare position, all operating at the same speed) is served by one director. The cross-office area consists of a common control with associated directors, translators, cross-office storage units, and reperforator-transmitters. When both channel speeds are used, two pools of cross-office storage units, each served by a director, are provided. These serve as temporary storage areas where tapes are grouped by precedence and outgoing line. Any cross-office storage unit can be accessed by any ILU, since there is no outgoing line unit (OLU) as such. The reader-transmitter of the cross-office storage unit transmits directly to the line and to a monitor reperforator for that line.

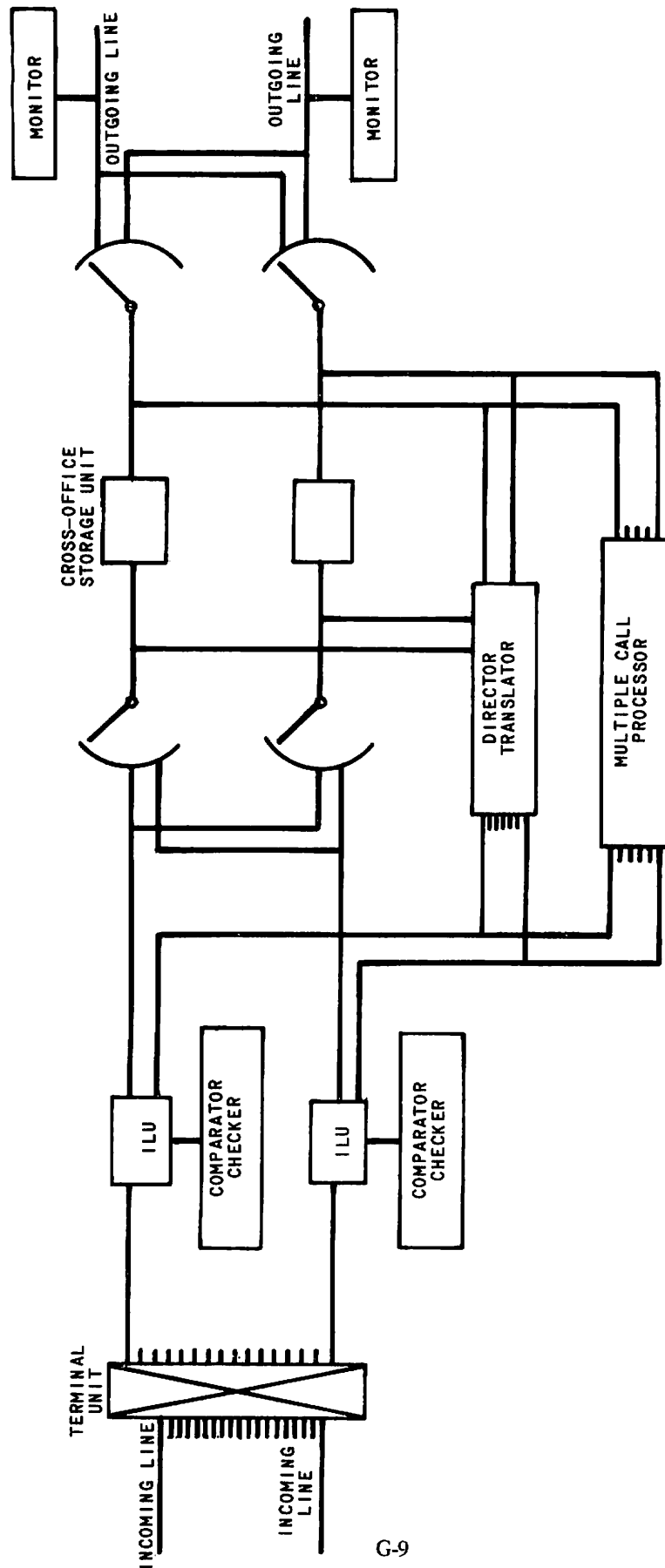
If an error occurs in the heading, the message automatically bypasses the cross-office unit and is sent to an intercept position. Here the errors are corrected, including any in the literal text.

When a message has a preemptive requirement, it is transmitted to an idle cross-office storage unit. A lower precedence message being transmitted to the required outgoing line is canceled, regardless of the time to completion, and the outgoing line is seized for the higher precedence message. The lower precedence message is repositioned in the cross-office storage unit by the attendant, and is then retransmitted in its entirety immediately following the preempting message. Routing line segregation is always employed in this center.

The incoming lines terminate on an intermediate distribution frame (IDF). Plugs and jacks facilitate connection of any line to any ILU. Each ILU consists of two reperforator-transmitters with associated channel designation serial number checkers. The transmitter sends the precedence and routing information as electrical signals to the director. If the message has a single routing indicator, it is then forwarded by the director to an individual cross-office storage unit; multiple ad-



OPERATIONS ROOM, AUTOMATIC MESSAGE-SWITCHING TAPE RELAY STATION
FIGURE G-3



G-9

AN/FGC-30 MESSAGE FLOW FUNCTIONAL DIAGRAM
FIGURE G-4

dress messages are processed by the multiple address unit before routing to various cross-office storage units. A director operating at 75 wpm serves all 60-wpm incoming lines; the 100-wpm lines are served by another director operating at 115 wpm. As much as 100 feet of perforated tape can be held in the incoming reperforator before being transmitted cross office. As messages are transmitted cross office, the tape is then placed on reels to maintain a permanent record of incoming traffic.

The director decides which cross-office unit will accept the message from a particular incoming line. After the outgoing line has been identified, and the cross-office unit has been selected, the director is released to serve another incoming line. The message, reperforated at the cross-office unit, is filed behind others of equal precedence in the unit, and these are then processed on a first-come, first-served basis. A preemptive message is directed to an idle cross-office unit. The message on the required outgoing line is canceled, the cross-office unit seizes the line, and the priority message is immediately transmitted.

When the director detects a multiple address message, control is turned over to the multiple address unit (MAU). This equipment acts as a director, and stores the precedence and the first routing indicator of the message. After identification of the outgoing line, the proper cross-office unit is seized, and the heading and routing indicator is read from the tape, a second cross-office unit is seized, and the heading and routing indicator are transmitted to it. All the cross-office units required by the routing indicators are seized and held. (A seized unit may receive several routing indicators, building up new multiple address messages for breakdown at further relay centers.) When all routing indicators have been transmitted, a multiple transmission of the remaining message is sent to all the held units. From this point on, transmission from each unit to its outgoing line is accomplished independently. Each MAU has a page printer that monitors all transactions, printing only sufficient characters of the heading for the operator to check the routing.

Each outgoing channel has an associated monitor typing reperforator. The reader-transmitter in the cross-office unit sends directly out to the line. Tapes in the cross-office unit and in the monitor unit are reeled to provide a permanent record.

Incoming messages with heading errors are automatically sent to the intercept position where the messages are reperforated. An attendant corrects the heading when possible or requests a repeat transmission. The corrected heading, followed by the message text, is inserted into a manual forwarding unit. This unit is electrically identical to a cross-office storage unit, and line

seizure is on the same basis. Transmission of the message to the line is automatic. Normally, if errors occur in the text, these are also corrected here.

3.4.2 Automatic Relay Center (82-B-1). The 82-B-1 is a fully automatic message-switching center (Figure G-5). Single- and multiple-address messages in the 5-unit International Number 2 Teleprinter Code in ACP 127 format are handled. This center consists primarily of self-contained ILU's and OLU's, which function as a complete switching center with no supplementary cross-office equipments. Each incoming or outgoing line can be arranged to operate at 60, 75, or 100 wpm.

The ILU director is the key element in this switching center. It reads, analyzes, and stores all routing indicators, and selects the proper outgoing line for each addressee. When the outgoing line is identified, the director sends a request to transmit to the selected unit. Cross-office transmission does not start until the outgoing line typing reperforator is free. A message being sent to one or more outgoing lines automatically brings about routing line segregation. An error in the heading sends the message to the intercept position for correction, after which it is reintroduced into the system. A preemptive message is given preferential treatment, but no outgoing messages are canceled in its favor.

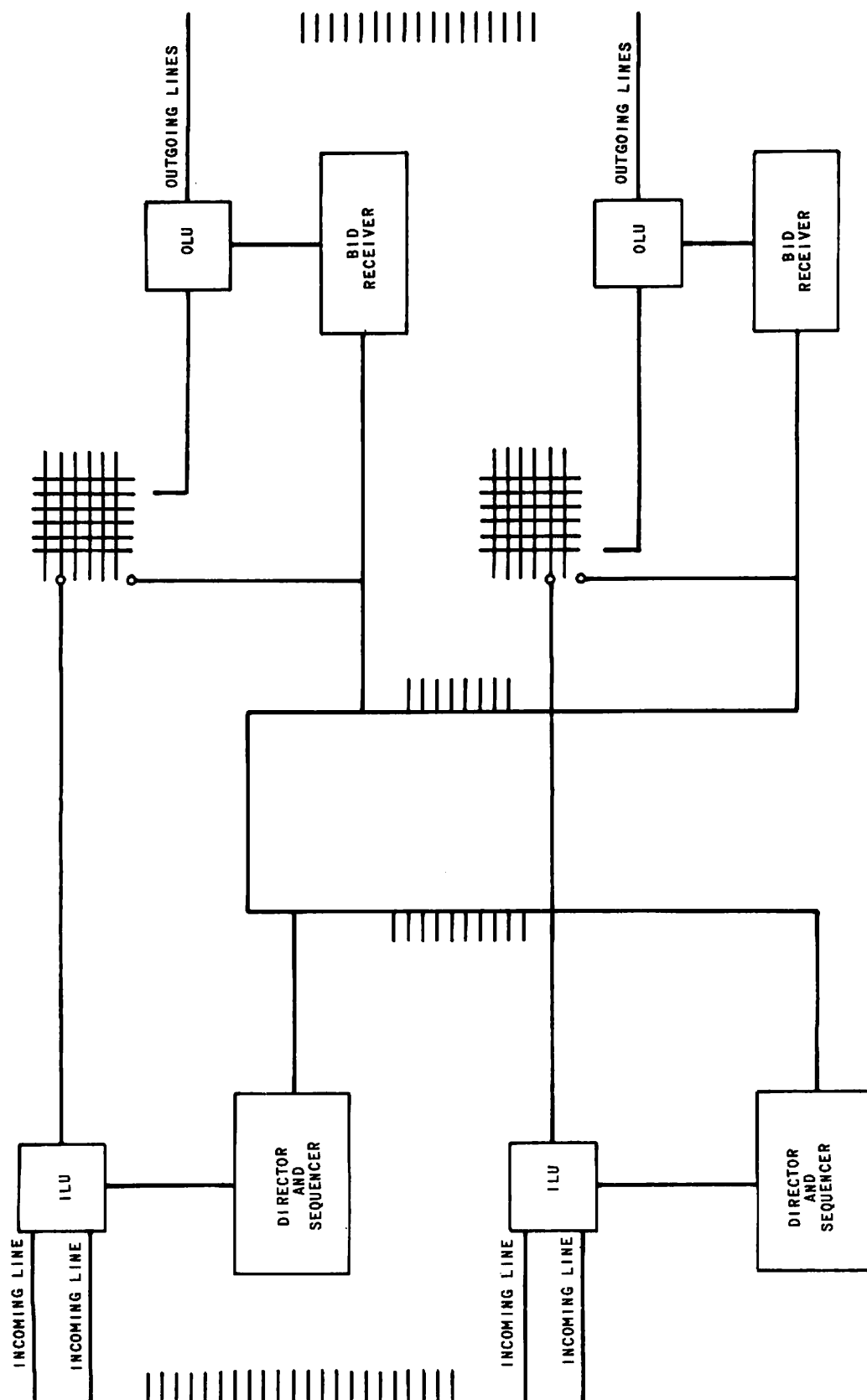
Each ILU contains three reperforator-transmitters—two for incoming lines, the other for the director circuit. These units copy the message and send the information cross office to the OLU. The director circuit reads and stores the routing indicators and precedence and indicates that the cross-office path is established wherein the message is automatically transmitted to the OLU and the director disconnects. If the request to transmit is denied, the ILU waits until the outgoing line is free. Storage for 12,000 characters is provided at each ILU.

When the ILU director detects a multiple-address message, it translates all the routing indicators, etc., but does not transmit until all the outgoing lines are available. A monitor records a tape copy of each outgoing message.

Each OLU serves four outgoing lines with associated reperforator-transmitter units controlled by two *bid* receiver circuits. Each OLU also contains two crossbar switches, which perform all cross-office connections. Each outgoing crossbar switch is capable of connecting to any ILU.

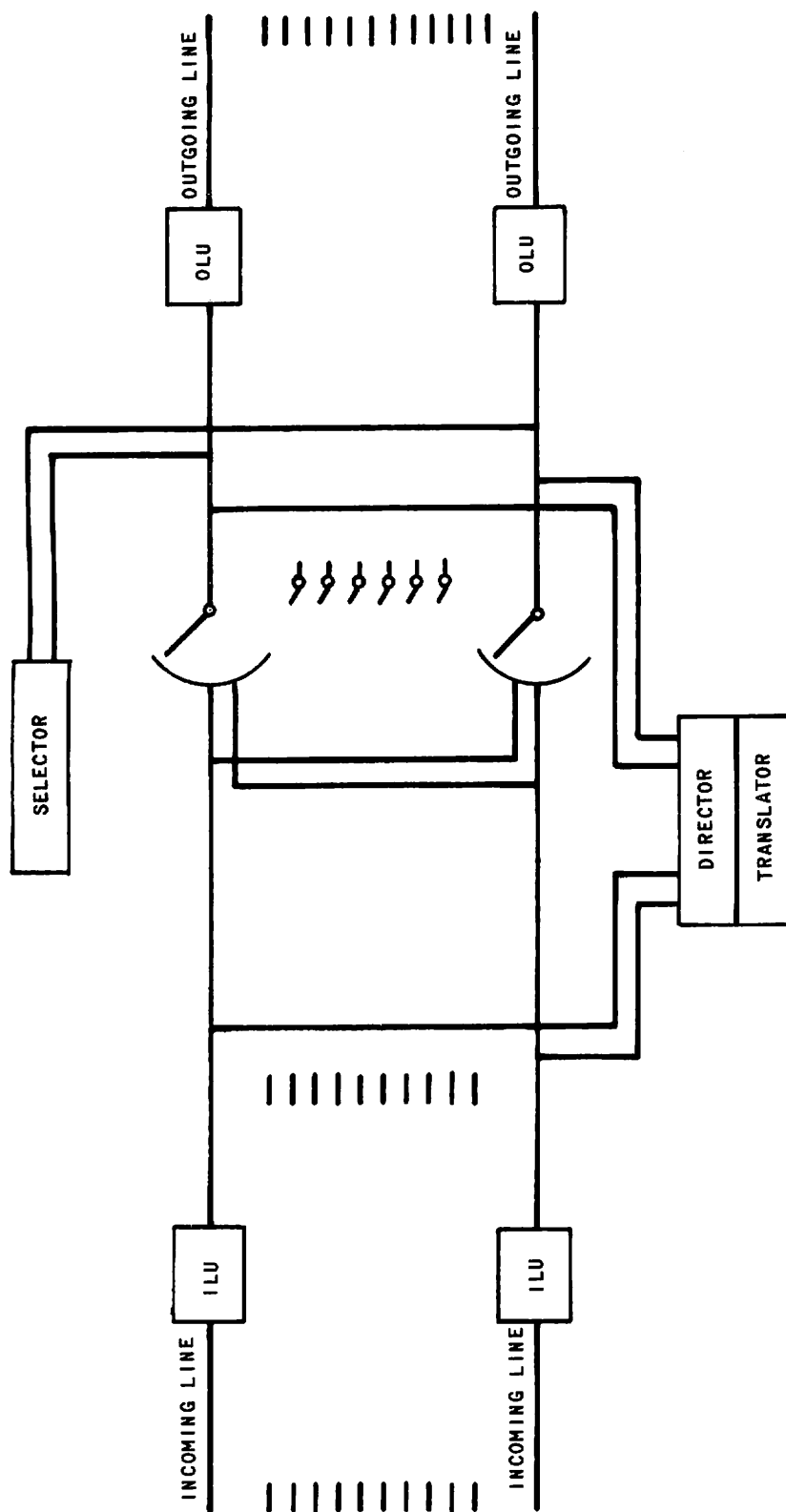
Incoming messages with heading errors are automatically sent to the intercept position where they are corrected and then reinserted into the system through a local send station.

3.4.3 Automatic Relay Center (Plan 55). The Plan 55 operates as a fully automatic message-switching center (Figure G-6) or as a semiautomatic (pushbutton) center if the cross-office routing director and translator are



G-11

82-B-1 MESSAGE FLOW FUNCTIONAL DIAGRAM
FIGURE G-5



PLAN 55 MESSAGE FLOW FUNCTIONAL DIAGRAM
FIGURE G-6

omitted. Single- and multiple-address messages in the 5-unit International Number 2 Teleprinter Code in ACP 127 format are handled. ILU's and OLU's, each serving two lines, can be independently arranged to operate at either 60 or 100 wpm. Each group of 13 ILU's (25 incoming lines plus one spare position) is served by one director. All incoming lines served by one director may operate at either 60 or 100 wpm. The cross-office area consists of a bank of rotary switches with associated director-translator and manual incoming-outgoing line selector. Precedence and routing indicators are transmitted to the director-translator where they are translated to identify the outgoing lines. The message is transmitted cross office at 200 wpm, directly to the reperforator in the OLU if it is idle; otherwise, the message waits. Sending the message to more than one outgoing line automatically brings about routing line segregation. The OLU affords temporary storage for all messages for that line. An error in the heading alerts the attendant, and the message is carried to the intercept position where the tape is corrected and reintroduced into the system. An incoming message having a preemptive requirement is given preferential treatment, by manual intervention.

Each ILU consists of two typing reperforators, two loop-gate transmitters with associated control, and alarm circuitry. The typing reperforators copy the message, and the loop-gate transmitter sends the information cross office to the OLU. The first sender of the loop-gate transmitter sends the routing information to the director-translator. If the typing reperforator in the selected OLU is free, the message is immediately transmitted by the second sender and the director disconnects. If there are more than four routing indicators, a multiple-address overflow unit at the intercept position and three outgoing lines receive the message. The first sender sends to the director-translator at 200 wpm; in this way, the incoming line speed is independent of the director. Each incoming line has storage capacity for 120,000 characters.

There is no message storage in the cross-office area. Equipment includes boards for connection indicators, traffic routing, and closeout indicators, and reperforator-transmitter sets for error correction. The traffic routing board is used for making temporary changes in the routing of messages by the use of patch cords and a jack field. If the director-translator is out of service, push-buttons on the connection-indicator board can be used to set up the cross-office switches between the ILU's and the OLU's.

A multiple-address message is not transmitted cross office until all routing indicators have been processed, and all outgoing lines have been identified. Routing

indicators per message are limited to nine. An incoming sender cannot access more than four outgoing lines at one time. All preliminary operations for a multiple-address message with up to four indicators are the same as for a single-address message. Messages to more than four outlets are transmitted to three OLU's and the multiple tape intercept position, from which point one message is reintroduced into the system and recycled.

Each OLU serves two lines, with typing reperforators and transmitter-distributor senders operating at either 60 or 100 wpm. Each OLU has storage capacity for 120,000 characters and can access any ILU. When a message with a preemptive requirement arrives at the OLU behind an accumulation of messages, an attendant manually places the preemptive message at the head of the queue.

Incoming messages, which cannot be automatically routed or processed because of a heading error, alert an attendant who corrects the error and then inserts the corrected message in the transmitter of the local send station.

3.5 Electronic Switching Center (AUTODIN)

3.5.1 General. The Defense Communications Agency (DCA) is presently building a worldwide Automatic Digital Network (AUTODIN), which will permit maximum use of circuits and improved speed-of-service.

The network comprises message and circuit switches, which will accept and relay traffic between card punch terminals, magnetic tape terminals, digital computers, teletypewriters, paper tape readers and punches, digital graphic transmitters and receivers, and digital voice subscribers. A subscriber equipped with any of the message terminal devices may communicate with other subscribers equipped with different message devices.

The Continental United States (CONUS) AUTODIN switching system is being augmented by modification of five presently installed switches and the addition of four similar switches. To satisfy digital requirements on a worldwide basis, ten new AUTODIN switches are being installed overseas.

3.5.2 Automatic Digital Message Switch (ADMS).

The main component of the network will be the Automatic Digital Message Switch (ADMS). The ADMS is an automatic, electronic digital message switch, employing primarily solid-state components for receiving, processing, and transmitting (on a store-and-forward basis) various forms of digital communications traffic. The switch assures accurate and reliable operation with provision for message accountability and security protection. Maintenance, both scheduled and unscheduled, will be performed while the switch is in operation. When connected to its tributaries and to other switches of

identical or compatible design, the ADMS will constitute an integral portion of a fully automatic worldwide store-and-forward message switching system.

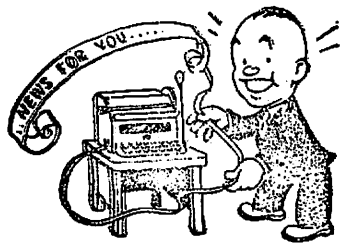
For asynchronous operation (start/stop), the ADMS will provide for any modulation rates between 45 and 160 baud. The character interval to include start/stop signals will be 7-11 units. The start/stop output will be capable of operating under the control of an external timing source (stepping).

For synchronous operation the ADMS will provide for input/output modulation rates of 75×2^m baud, where $m = 0, 1, 2, 3, 4, 5$, or 6 . An 8-unit interval per char-

acter will be standard for synchronous operation. The intrasystem trunks will use duplex operation with automatic error and channel controls and employ synchronous transmission.

The ADMS hardware will be of modular construction and provision will be made to permit the number of line terminations to expand from a minimum of about 50 to a maximum of approximately 100 duplex lines, for installations classed as a 100-line ADMS; and from a minimum of about 120 to a maximum of approximately 200 duplex line terminations for installations classed as a 200-line ADMS.

PART H
APPENDIXES



Appendix I

Performance Standards of Military Teletypewriter Operation

1.0 GENERAL

Military Communication System Technical Standards (MIL-STD-188B) is to be used in design, installation, and operation of new communication systems. It is not intended that existing systems will be immediately converted to comply with the requirements of this standard. The reference numbers in this section are paragraph numbers in the revised MIL-STD-188B dated 24 February 1964.

Only the standards which apply specifically to teletypewriter equipment are included in this section. It will be noted that the teletypewriter (5-unit, start/stop) is treated as an interim standard type of equipment, while the 8-unit code type teletypewriter is considered the standard type to be used wherever practicable. The increasing requirement for transmission of digital data and the need for interchange of information among information processing systems and communication systems influenced the Department of Defense in adopting the 8-level ASCII code as the Military Standard. The need for an adequate number of characters, each with a unique meaning for information, graphics, and error control, could not be provided by the 5-level coded character set.

2.0 TELETYPEWRITER (5-UNIT, START-STOP) (REF PARAGRAPH 3.4.1.1)

The use of this type of equipment is no longer standard. However, due to its widespread use this equipment will be operational for an indeterminate interval. During this interval the following standards shall govern.

2.1 Signal Characteristics

The U.S. military standard start/stop signal is the 5-unit, International No. 2 alphabet (American variation).

For transmitting equipment, the standard start/stop character interval for 5-unit code printing telegraph shall

be seven units; 1-unit start element, five intelligence elements, and 1-unit stop element.

For receiving equipment, the standard start/stop character interval for 5-unit code printing telegraph shall be 6.6 units, i.e., the receive device shall correctly accept the next character interval by at least 6.6-unit intervals from the start mark to space transition of the previous character interval.

The standard modulation rate for printing telegraph below 150 baud shall be 50.0 and 75.0 baud.

In words per minute (wpm) for the 7-unit character interval; 50 baud = 71.4 wpm and 75 baud = 107.1 wpm.

2.2 Functional Description of Electromechanical Printing Telegraph Equipment

The basic unit used in printing telegraph is the page printer. This is a device that generally types, on paper fed from a roll, a line of printed characters administratively limited within US/NATO military circles to 69 per line. There are two standard fonts in use within the Defense Communications System, i.e., Weather Symbols and Communication Symbols.

Punch tape equipment perforates a tape of one-inch width with perforations representing a mark or binary one. No perforation represents a space or binary zero.

Mechanical tape readers are of two basic classes:

(a) Coincident selection in which all pins of the tape reader sense the tape simultaneously.

(b) Sequential selection in which sensing pins 1, 2, 3, 4, and 5 are successively presented to the tape to determine the presence or absence of a perforation. This type is seldom used.

2.3 Performance Characteristics of Electromechanical Printing Telegraph Equipment

The performance characteristics of electromechanical printing telegraph equipment are expressed in distortion

tolerances. The distortion percentages specified are applicable at the modulation rate employed by the equipment.

Two sets of tolerances are specified for some equipment, one for high performance equipment and the other for low performance equipment. These categories are not rigidly defined, but generally speaking mechanical printing telegraph may be considered high performance if it operates correctly (essentially continuously for 1,500 hours at 75 baud, 7-unit code).

The distortion tolerances for transmitting and receiving devices are tabulated in Tables I-1 and I-2, respectively.

3.0 TELETYPEWRITER EQUIPMENT (8-UNIT CODE TYPE) (REF PARAGRAPH 3.4.1.2)

This type of teletypewriter set is the recommended standard and shall be used wherever practicable. The standard code for teleprinter equipment shall be the same for digital data communication equipment.

The basic code is composed of eight units, i.e., seven information units and a parity bit.

For transmission, the eighth bit is used for odd parity check; that is, this bit is so set that the sum of the binary ones of the 8-code character is always odd, an even sum indicating an error. For punched tape, all parity bits

TABLE I-1

PERFORMANCE CHARACTERISTICS OF TRANSMITTING DEVICES

TYPE OF EQUIPMENT	TYPE OF SELECTION	OUTPUT DISTORTION REQUIREMENTS	
		HIGH PERFORMANCE EQUIPMENT	LOW PERFORMANCE EQUIPMENT
Electromechanical Keyboards, Tape Readers Electromechanical with Electronic Outputs	Sequential	1% Mark-0-1% Space	4% Mark-0-4% Space
	Coincident	1% Mark-0-1% Space	3% Mark-0-3% Space
	Sequential or Coincident	1% Mark-0-1% Space	

TABLE I-2

PERFORMANCE CHARACTERISTICS OF RECEIVING DEVICES

TYPE OF EQUIPMENT	SWITCHED BIAS DISTORTION	INPUT DISTORTION TOLERANCE		
		BIAS DISTORTION	END DISTORTION	CYCLIC DISTORTION
Electromechanical High Performance Equipment Low Performance Equipment	45% Mark-0-45% Space	45% Mark-0- 45% Space	45% Mark-0- 45% Space	22.5% Mark-0- 22.5% Space
	30% Mark-0-30% Space	30% Mark-0- 30% Space	30% Mark-0- 30% Space	15% Mark-0- 15% Space
Electromechanical with Electronic Selectors	49% Mark-0-49% Space	49% Mark-0- 30% Space	49% Mark-0- 49% Space	24.5% Mark-0- 24.5% Space

are automatically reversed to give even parity. This parity bit is always transmitted last.

3.1 Signal Characteristics

The preferred transmitted start/stop character interval of 8-unit coded character sets for printing telegraph and data equipment shall be 10 units, i.e., 1-unit start element, 8-unit intelligence elements, and 1-unit stop element. An 11-unit interval is permissible where such operation is technically more satisfactory.

For receiving equipment, the standard start/stop character interval (as regards the functioning of the receiver apparatus) for 8-unit coded character sets utilizing a 10-unit character interval shall be 9.5 units; i.e., the receiver device shall be prepared to correctly accept the next character interval at 9.5-unit intervals from the mark-to-space transition of the previous character interval.

An 8-unit character interval shall be standard for synchronous transmission.

The modulation rates for digital transmission shall be:

(a) 25 baud and above: 25.0, 50.0, or n multiplied by 75.0 baud where n is a positive integer. The preferred rates shall be:

(1) 25.0

(2) 50.0

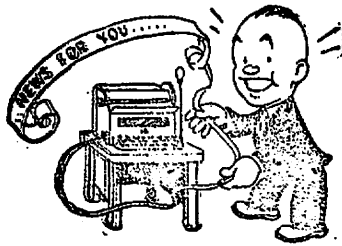
(3) 75.0×2^m , where m is zero or a positive integer.

(b) Below 25 baud: the preferred rates are 25.0 divided by 2^m .

3.2 Performance Characteristics of 8-Unit Code-Type Teletypewriter Equipment

The transmitting device shall produce not more than 1% Mark-0-1% Space distortion of the transmission time or signal element duration for electronic devices and 3.5% Mark-0-3.5% Space for electromechanical devices as measured in relation to the theoretically correct unit interval duration.

The receiving equipment shall tolerate distortion as tabulated in Table I-2.



Appendix II

Definition of Terms

Analog Signal: A nominally continuous electrical signal that varies in some direct correlation to a signal impressed on a transducer. The electrical signal may vary its frequency or amplitude, for instance, in response to change in phenomena or characteristics such as sound, light, heat, position, or pressure.

Arhythmic Transmission: The received characters may follow one another directly and rhythmically, as from a paper tape transmitter-distributor, or they may arrive separated by quiescent intervals of varying lengths, as when received from a keyboard transmitter. In the latter case (varying lengths of quiescent intervals), the transmission is said to be *arhythmic*. NOTE: Sometimes used for start/stop. The latter term is preferred.

Asynchronous Transmission: A transmission process such that between any two significant instants in the same group* there is always an integral number of unit intervals. Between two significant instants located in different groups, there is not always an integral number of unit intervals.

Baud: The unit of modulation rate. One baud corresponds to a rate of one unit interval per second. The modulation rate is expressed as the reciprocal of the duration in seconds of the unit interval. Example: If the duration of the unit interval is 20 milliseconds, the modulation rate is 50 bauds.

Baudot Code: A term incorrectly used for various 5-unit codes, intended to honor Emile Baudot, who introduced a 5-unit code in 1874. For correct definition, see Part A, paragraph 2.0. The term *5-unit code* is preferred.

Binary Code: A code composed of a combination of entities, each of which can assume one of two possible states.

Binary Digit: An information state in binary notation, e.g., 0 or 1.

Bit: The abbreviation for binary digit. In information theory, it is the unit of information content.

*In data transmission, this group is a block or a character. In telegraph, this group is a character. NOTE: It is recommended that this term be dropped from telegraph (low-speed) terminology and be replaced in all instances by the proper term it was intended to describe, i.e., start/stop.

Break: To break, in a communication circuit, is for the receiving user to interrupt the sending user and take control of the circuit; used especially in connection with half-duplex telegraph circuits and two-way telephone circuits equipped with voice-operated devices.

Buffer, Data: A storage device used to compensate for a difference in rate of flow of information or time of occurrence of events.

Carrier: A wave suitable for modulation by the intelligence to be transmitted over a communication system. The carrier can be a sinusoidal wave or a recurring series of pulses.

CCITT: The International Telegraph and Telephone Consultative Committee (Comite Consultatif International Telegraphique et Telephonique). The CCITT is an international organization with headquarters at Geneva, dedicated to the solution of technical and organizational problems peculiar to the fields of teleprinter and telephone traffic, setting forth recommendations and standards to be used by the participating administrations. This organization is a merger (1956) of the CCIT (telegraph) and the CCIF (telephone). Within the category of telegraphy, the work of the CCITT embraces the following items, each item being handled by a separate committee group:

- A. Organization and Procedures
- B. Telegraph Transmission
- C. Teleprinter Apparatus
- D. Facsimile Equipment
- E. Telegraph Switching
- F. Operation
- G. Regulations and Tariffs
- H. Telex Service and Leased Circuits
- I. Glossaries, Symbols, Definitions, etc. (TS, 323)

Central Office: (Also called Switching Center, Switching Facility, Switching Exchange.) An installation in a communication system in which switching equipment is used to interconnect communication circuits on a message switching or circuit switching basis.

Channel: In electric communication, a channel is a one-way path for transmitting electrical signals. Several channels may share a common path as in carrier

systems. In this case, each channel is allocated a particular frequency band which is reserved for it.

Channel, Telephone: A telephone channel is a channel suitable for the transmission of telephone signals.

Channel, Telephone, Carrier: A carrier telephone channel is a telephone channel employing carrier transmission.

Character, Code: A code character is a particular arrangement of code elements, used in a code to represent a single value or symbol.

Character Interval: The total number of unit intervals (including synchronizing, intelligence, error checking, or control bits) required to transmit any given character in any given communication system. Extra bits which are not associated with individual characters are not included.

Circuit: The complete electrical path between end-terminal instruments over which two-way telecommunications are provided.

Circuit Reliability: The percent of time a circuit was available to the user during a specified period of time.

Circuit reliability =

$$\frac{(1 - \text{total circuit outage time})}{\text{total time}} \times 100\%$$

NOTE: Total circuit outage time equals the time any portion of the circuit did not function and substitute facilities were not successfully employed to restore the circuit.

Clock: A reference source of timing information for a machine or system.

Code (Telegraph or Data): A system of rules and conventions according to which the telegraph signals forming a message (or the data signal forming a block) should be formed, transmitted, received, and processed.

Code Conversion: The process by which a code of some predetermined bit structure (for example, 5, 7, 14 bits per character interval) is converted to a second code with more or less bits per character interval. No alphabetical significance is assumed in this process. In certain cases, e.g., the conversion from start/stop telegraph equipment to synchronous equipment, a code conversion process may consist only of discarding the stop and start bits and adding a sixth bit to indicate the stop and start condition. In other cases, it may consist of addition or deletion of control and/or parity bits.

Code Element: A code element is one of the discrete conditions or events in a code, for example, the presence or absence of a pulse. One of a finite set of parts of which the characters in a given code may be composed.

Control Character: A character whose occurrence in a particular context initiates, modifies, or terminates a control operation.

Cryptographic Synchronous Operation: A method of on-line crypto-operation in which terminal cipher equipments have timing systems to keep them in step. Synchronism of the system is independent of the traffic passing on the trunk/circuit concerned.

Digital Signal: A nominally discontinuous electrical signal that changes from one state to another in discrete steps. The electrical signal could change its amplitude or polarity, e.g., in response to outputs from computers, teletypewriters, etc. Analog signals may be converted to a digital form by quantizing.

Direct Current Telegraphy: A form of telegraph in which transmission is effected by a direct current applied to the line, under the control of the sending apparatus.

Distortion, Bias: Distortion affecting a two-condition (or binary) modulation in which all the significant intervals corresponding to one of the two significant conditions have uniformly longer or shorter duration than the corresponding theoretical durations.

Distortion, Characteristic: Distortion caused by transients which, as a result of modulation, are present in the transmission channel and depend on its transmission qualities.

Distortion, Cyclic (of Telegraph Signals): Distortion which is neither characteristic, bias, nor fortuitous. In general, it has a periodic character. Its causes are, for example, irregularities in the duration of contact time of the brushes of a transmitter-distributor or interference by disturbing alternating currents, etc.

Distortion, Degree of Individual, of a Particular Significant Instant (of a Modulation or of a Restitution): Ratio to the unit interval of the displacement, expressed algebraically, of this significant instant from an ideal instant. This displacement is considered positive when a significant instant occurs after the ideal instant. The degree of individual distortion is usually expressed as a percentage.

Distortion, Delay (of a Transmission System): That distortion caused by the difference between the maximum transit time and the minimum transit time of frequencies within a specified band. Also called time delay distortion and phase distortion.

Distortion, End (of Start/Stop Teletypewriter Signals): The shifting of the end of all marking pulses from their proper positions in relation to the beginning of the start pulse.

Distortion, Fortuitous (of Telegraph Signals): Distortion resulting from causes generally subject to random laws, for example, accidental irregularities in the operating of the apparatus and moving parts, disturbances affecting the transmission channel, etc.

Distortion, Isochronous: The deviation in duration of pulses from unit interval, or exact multiple of unit interval, expressed as a percentage of the standard unit interval.

Distortion, Peak: Peak distortion is the largest total distortion of telegraph signals noted during a period of observation.

Distortion, Teletypewriter Signal (of Start/Stop Teletypewriter Signals): The shifting of the transition points of the signal pulses from their proper positions relative to the beginning of the start pulse. The magnitude of the distortion is expressed in percent of a perfect unit pulse length. The total distortion is the algebraic sum of the bias and the characteristic and fortuitous distortions.

Dot-Cycle: A dot-cycle is one cycle of a periodic alternation between two signaling, it consists of a dot, or marking element, followed by a spacing element.

Duplex (Full Duplex) Operation: A type of operation in which simultaneous two-way conversations, messages, or information may be passed between any two or more given points.

Duplex (Half Duplex) Operation: A circuit designed for duplex operation, but which, on account of the nature of the terminal equipment, can be operated alternately only on a send-receive basis.

End Instrument: A device which is connected to the terminal of a circuit and used to convert usable intelligence into electrical signals or vice-versa.

Error-Correcting Code: A code in which each telegraph or data signal conforms to specific rules of construction so that departures from this construction in the received signals can be automatically detected, and permit the automatic correction at the receiving terminal, of some or all of the errors. Such codes require more signal elements than are necessary to convey the basic information.

Error-Detecting Code: A code in which each telegraph or data signal conforms to specific rules of construction, so that departures from this construction in the received signals can be automatically detected. Such codes require more signal elements than are necessary to convey the fundamental information.

Error Rate (Bit, Block, Character, Element): The ratio of the number of bits, elements, characters, or blocks incorrectly received to the total number of bits, elements, characters, or blocks sent.

Error Rate, Residual (Undetected Error-Rate): The ratio of the number of bits, elements, characters, or blocks incorrectly received but undetected or uncorrected by the error-control equipment, to the total number of bits, unit elements, characters, or blocks sent.

Facsimile Telegraphy: A system of telegraphy providing reproduction of fixed images (photographic or other-

wise) in the form, and possibly in depth of tone or color, of the original document; whether written, printed, or pictorial.

Fail-Safe Control: A control so designed that a control circuit failure cannot cause a dangerous condition under any circumstance.

FIELDATA Code: Binary code of 8 bits of which 6 bits are information, 1 control, and 1 parity (error detecting), developed for Army Signal Corps as 6-bit alphanumeric code with Baudot code equivalents.

Five-Unit Start/Stop Code: The 5-unit start/stop code is an equal-length code consisting of a spacing (start) element and five successive information or selective elements, all of equal duration, followed by a marking (stop) element, which may vary in duration but may never be less than a unit interval.

Four-Wire Circuit: A four-wire circuit is a two-way circuit using two paths so arranged that the electric waves are transmitted in one direction only by one path and in the other direction only by the other path. NOTE: The transmission paths may or may not employ four wires.

Fox: Abbreviated form for the recommended standard test sentence, "The quick brown fox jumps over the lazy dog," which contains every letter in the English alphabet in its composition.

Frequency Shift: System of telegraph teletypewriter operation in which the mark signal is one frequency and the space signal a different frequency. NOTE: CCITT recommends that mark is lower frequency; also, the difference between mark and space will vary in different systems, e.g. 170 cps U.S.A., 120 cps Europe.

Frequency Shift Keying: Frequency shift keying is that form of frequency modulation in which the modulating wave shifts the output frequency between predetermined values, and is characterized by continuity of phase during the transition from one signalling condition to the other.

F.R.X.D. (Fully Automatic Reperforator Transmitter-Distributor): A perforated tape transmitter in which a tape reading head, moving along the tape, or any other similar device, ensures the transmission of all the signals recorded by perforation, including the last one.

Grade of Service: The proportion of calls not completed on demand. This may be an instantaneous measure (e.g., at the busy-hour period), an average measure for the system, or an individual user measure. It includes calls incompleting for all reasons except error by the calling user and busy condition of the called user.

Graphic: A written or printed form or shape, e.g., 3 A e % ,.

Ground-Return Circuit: A ground-return circuit is a circuit which has a conductor (or two or more in parallel) between two points and which is completed through the ground or earth.

Group: An assembly of a specified number of circuits, normally 12, whose frequency bands occupy adjacent bands in a frequency spectrum. Where no ambiguity arises, the term group may also be applied to the corresponding number of channels in either direction of transmission.

Guard Band: A frequency band between two channels which gives a margin of safety against mutual interference.

High-Frequency Carrier Telegraphy: That form of carrier telegraphy in which the carrier currents have their frequencies above the range transmitted over a voice-frequency telephone channel.

High Performance Equipments: Those equipments having sufficiently exacting characteristics to permit their use in trunk or link circuits. NOTE: Requirements for global and tactical high performance equipments may differ.

Holding Time: Period of time during which a trunk or circuit is in use. It includes, in particular, call duration (conversation time), operating time (time taken both by operators and switching equipment) and the time required for the exchange of service information, etc.

Idle Condition: A condition that exists when transmission of information and control signals is not in progress.

Information: Any facts or data which can be used, transferred, or communicated.

Input-Output Device: Any equipment which introduces data into or extracts data from a data communication system.

Interface: A concept involving the specification of the interconnection between two equipments or systems. The specification includes the type, quantity, and function of the interconnection circuits and the type and form of signals to be interchanged via those circuits.

Internal Bias (Teletypewriter): Internal bias is that bias, either marking or spacing, that may occur within a start/stop teletypewriter receiving mechanism and which will have the same effect on the margins of operation as bias external to the receiver.

Keyboard: The portion of a manual telegraph instrument consisting of keys, the depression of any one of which causes the transmission, or the perforation in a tape, of the corresponding signal combination.

Keying: Keying is the forming of signals, employed in telegraph transmission, by the modulation of a direct current or other carrier between discrete values of some characteristic.

Keying, Electronic: Electronic keying is a method of keying in which the control is accomplished by electronic means.

Keying, Frequency-Shift: See frequency shift keying.

Keying, Single-Tone: Single-tone keying is that form of keying in which the modulating wave causes the carrier to be modulated with a single tone for one condition, which may be either marking or spacing, and the carrier is unmodulated for the other condition.

Keying, Two-Tone: Two-tone keying is that form of keying in which the modulating wave causes the carrier to be modulated with one frequency for the marking condition and modulated with a different frequency for the spacing condition.

Link: (a) A portion of a communication circuit; (b) a channel or circuit designed to be connected in tandem with other channels or circuits; (c) in automatic switching, a link is a path between two units of switching apparatus within a central office. NOTE: The term link should be defined or qualified when used. It is generally accepted that the signals at each end of the link are in the same form.

Link Encryption: Technique whereby transmission links are equipped with cryptographic devices connected at the link terminals.

Local End (Telegraph, with its Termination): The whole of the apparatus, lines, telegraph repeaters, and any control units between the apparatus and the first (or last) point of the communication facility where the transmission quality may be measured.

Local Line: See "Loop, Line."

Loop: A loop is a single message circuit from a switching center and/or individual message distribution point to the terminals of an end instrument.

Loop, Line: The portion of a radio or wire circuit that connects a user's end instrument and a central office.

(Synonymous terms are *local line* and *user's line*.)

Manual Exchange: An exchange at which the interconnection of circuits is effected manually.

Manual System: A system in which operators receive the calls and perform the necessary switching operations to complete the connection between calling and called parties.

Margin: (a) In printing telegraphy, margin is that fraction of a perfect signal element through which the time of selection may be varied in one direction from the normal time of selection, without causing errors while signals are being received. There are two distinct margins, determined by varying the time of selection in either direction from normal. (b) The maximum degree of distortion which can affect the restitution of all the signals a telegraph apparatus should be able to receive without ceasing to translate them correctly.

Marking and Spacing Intervals: In telegraph communication, marking intervals are the intervals which correspond, according to convention, to one condition or position of the originating transmitting contacts, usually

a closed condition; spacing intervals are the intervals which correspond to another condition of the originating transmitting contacts, usually an open condition. NOTE: The terms mark and space are frequently used for the corresponding conditions. The waves corresponding to the marking and spacing waves, respectively.

Marking: (a) In Morse, corresponds to those portions of dot and dash signals which, for example, when actuating a Morse inker, will cause the inker to mark the paper. (b) In printing telegraphy, corresponds to that significant condition which results in an active selecting operation in a receiving apparatus. NOTE 1: In start-stop automatic transmission, the term corresponds to the perforation of a hole in the tape. NOTE 2: In standardized start-stop telegraphy, the term corresponds to the stop element. In isochronous systems, the terms which are arbitrarily assigned to one or the other of the two signaling conditions.

Spacing: (a) In Morse, corresponds to the spaces separating marking signals and to the spaces separating complete characters. (b) In printing telegraphy, corresponds to that significant condition which results in a passive selecting operation in a receiving apparatus. NOTE 1: In start/stop automatic transmission, the term corresponds to the absence of perforation in the tape. NOTE 2: In standardized start/stop telegraphy, the term corresponds to the start element. (c) In isochronous systems, the term which is assigned to the non-marking signaling condition.

Message: An ordered selection from an agreed set of signs or symbols intended to communicate information from a source to one or more destinations. In telegraphic and data communications a message is composed of three parts as follows: (1) A heading containing a suitable indicator of the beginning of the specific message together with information on any or all of the following: the source and destination, date and time of filing, and routing or other transmission information. (2) A body containing the information or advice to be communicated. (3) An ending containing a suitable indicator of the conclusion of the specific message, either explicit or implicit.

Modulate: To vary the amplitude, frequency, or phase of an oscillation, usually at a signal frequency.

Modulating Wave: A wave which causes a variation of some characteristic of the carrier.

Modulation: The process by which the essential characteristics of a signal wave (the modulating wave) are impressed upon another wave (the carrier wave).

Modulation, Amplitude (AM): Modulation in which the amplitude of the carrier is the characteristic varied.

Modulation, Angle: Modulation in which the phase angle of a sinewave carrier is the characteristic varied.

NOTE: Frequency and phase modulation are particular forms of angle modulation.

Modulation, Frequency (FM): Frequency modulation is angle modulation in which the instantaneous frequency of a sinewave carrier is caused to depart from the nominal frequency by an amount proportional to the instantaneous amplitude value of the modulating wave.

Modulation, Isochronous: Modulation (or demodulation) in which the time interval separating any two significant instants is theoretically equal to the unit interval or to a multiple of this.

Modulation Rate: Reciprocal of the unit interval measured in seconds. (This rate is expressed in bauds.)

Modulation Rate Converter: A store and release device can be used as an interface when teletypewriter circuits of different operating baud rates are to be interconnected. The modulation rate converter finds application in such areas as those involving the electrical connection between 45.5- and 75.0-baud teletypewriter equipment.

Modulation, Significant Condition of A: A condition assumed by the appropriate device corresponding to the quantized value (or values) of the characteristic (or characteristics) chosen to form the modulation. The following equivalent designations are used to identify the significant conditions for binary modulation:

<i>Passive</i>	<i>Active</i>
A	Z
0	1
Current off	Current on
Tone off	Tone on
Space	Mark
—	+
No hole (paper tape)	Hole (paper tape)

Multichannel/Multiplex: The utilization of a common channel (or transmission path) to carry two or more simultaneous channels, either by splitting the frequency band transmitted by the common channel into narrower bands, each of which constitutes a distinct channel (frequency-division-multiplex), or by allotting this common channel in turn, to the use of sequential time intervals, thus constituting different incremental channels (time-division-multiplex).

Multichannel Telegraph System: A telegraph transmission system in which two or more telegraph channels are derived from a single transmission path, either by time or frequency division.

Multichannel Telegraph, Voice Frequency: Telegraphy using two or more carrier currents whose frequencies are within the voice frequency (vf) range.

Multiplexing, Frequency-Division (FDM): A device or process for the transmission of two or more channels

over a common path by using a different frequency band for each channel.

Multiplexing, Time-Division: The process of transmitting two or more channels over a common path by using different time intervals for different channels.

Network, Telegraph: A group of stations, installations, centers, and channels coordinated for the purpose of providing a telegraph service.

Neutral Direct Current Telegraph System (Single-Current Transmission): (a) A telegraph system that employs current during marking intervals, and zero current during spacing intervals for transmission of signals over the line. (b) A method of signaling in which transmission is effected by means of unidirectional currents.

Off-Line Cryptographic Operation: A method of operation in which encryption and transmission or reception and decryption are performed in separate steps, rather than automatically and simultaneously.

On-Line Cryptographic Operation: A method of operation whereby messages are automatically encrypted and simultaneously transmitted from one station to one or more stations, where reciprocal equipment is automatically operated to permit reception and simultaneous decryption of the message.

On-Line Secured Communications System: Any combination of interconnected communication centers partially or wholly equipped for on-line cryptographic operation and capable of relaying or switching message traffic, using on-line cryptographic procedures.

Open-Circuit Working: A method of single-current operation in which no current flows in the circuit while the transmitting device is at rest.

Open Wire: An open wire is a conductor separately supported above the surface of the ground. NOTE: An open wire is usually a conductor of a pole line.

Open-Wire Circuit: An open-wire circuit is a circuit made up of conductors separately supported on insulators. NOTE: The conductors are usually bare wire, but they may be insulated by some form of continuous insulation. The insulators are usually supported by crossarms or brackets on poles.

Operator: One who manipulates the manual controls of a machine.

Parity Check: A method of detecting errors by counting the number of 1's in each word or column. Syn: odd-even check. An extra bit in each word, or an extra word in each column, causes the correct count to be always odd (odd parity) or even (even parity). See error-detecting code.

Polar Direct Current Telegraph System: A polar direct current telegraph system is one that employs positive and negative currents for transmission of signals over the line.

Polarential Telegraph System: A polarential telegraph system is a direct current telegraph system employing polar transmission in one direction and a form of differential-duplex transmission in the other direction.

NOTE: Two kinds of polarential systems, known as types A and B, are in use. In half-duplex operation of a type A polarential system, the direct current balance is independent of line resistance. In half-duplex operation of a type B polarential system, the direct current balance is substantially independent of the link leakage.

Printing Telegraphy: Printing telegraphy is that method of telegraph operation in which the received signals are automatically recorded in printed characters.

Pulse: A signal characterized by the rise and decay in time of a quantity whose value is normally constant.

Pulse Duration: (Pulse length, pulse width) The duration of a pulse is the time interval between the points on the leading and trailing edges at which the instantaneous value bears a specified relation to the pulse amplitude.

Pulse Regeneration: Pulse regeneration is the process of restoring a series of pulses to their original timing, form, and relative magnitude.

Range (Orientation Range): In printing telegraphy, range is the fraction of a perfect signal element through which the time of selection may be varied so as to occur earlier or later than the normal time of selection, without causing errors while signals are being received. The range of a printing telegraph receiving device is commonly measured in percent of a perfect signal element by adjusting the range finder.

Redundant Code: A code using more signal elements than necessary to represent the intrinsic information.

Reliability: Capability of a system or any element thereof to perform, without failure, a specified function under given conditions for a specified period of time. It may be stated in terms of probability (expressed in percent or, preferably, in a decimal number less than unity).

Reliability, Communications: The assurance that the transmission of information from the communications station serving the originator to the communications station serving the addressee will arrive in a timely manner and without loss of meaning.

Repeater: A repeater is a combination of apparatus for receiving either one-way or two-way communication signals and delivering corresponding signals, which are either amplified or reshaped or both. A repeater for one-way communication signals is termed a *one-way repeater* and one for two-way communications signals a *two-way repeater*.

Repeater, Carrier: A carrier repeater is a repeater for use in carrier transmission.

Repeater, Half-Duplex: A half-duplex repeater is a duplex telegraph repeater provided with interlocking

arrangements which restrict the transmission of signals to one direction at a time.

Repeater, Regenerative: A repeater in which the signals retransmitted are reshaped and retimed. (Performs pulse regeneration.)

Repeater, Telegraph: A telegraph repeater is an arrangement of apparatus and circuits for receiving telegraph signals from one line and retransmitting corresponding signals into another line.

Signal Element: Each of the parts constituting a telegraph or data signal and distinguished from the others by its nature, magnitude, duration, and relative position (or by one or some of these features only).

Significant Instants: The instants at which the successive significant conditions recognized by the appropriate device of the modulation or restitution begin. Each of these instants is determined as soon as the appropriate device takes up the significant condition usable for a recording or a processing. (See transition, signal.)

Significant Interval: Time interval between two consecutive significant instants.

Simplex Operation: That type of operation which permits the transmission of signals in either direction alternately.

Spacing: See marking and spacing.

Speed of Transmission: The instantaneous rate at which information is processed by a transmission facility. This quantity is usually expressed in characters per unit time or bits per unit time. (Rate of Transmission is more common usage, see modulation rate.)

Speed of Transmission, Effective: The rate at which information is processed by a transmission facility expressed as the average rate over some significant time interval. This quantity is usually expressed as average characters per unit time or average bits per unit time. (Rate of transmission, average is more common usage.)

Speed of Transmission, Peak: See speed of transmission. (Rate of transmission, instantaneous is more common usage.)

System, Bridge Duplex: A bridge duplex system is a duplex system based on the Wheatstone bridge principle in which a substantial neutrality of the receiving apparatus to the sent currents is obtained by an impedance balance. Received currents pass through the receiving relay which is bridged between the points that are equipotential for the sent currents.

System, Communications: An overall term used to describe communication facilities from an engineering aspect, including all the associated equipment.

System, Differential Duplex: A differential duplex system is a duplex system in which the sent currents divide through two mutually inductive sections of the receiving apparatus, connected respectively to the line and to a

balancing artificial line, in opposite directions. Therefore, there is substantially no net effect on the receiving apparatus, whereas the received currents pass mainly through one section, or through the two sections in the same direction, and operate the apparatus.

System, Direct Current Quadruplex: A direct current quadruplex system is a direct current telegraph system which affords simultaneous transmission of two messages in each direction over the same line, operation being obtained by superposing neutral telegraph upon polar telegraph.

System, Start/Stop: A system in which each group of code elements corresponding to an alphabetical signal is preceded by a start signal which serves to prepare the receiving mechanism for the reception and registration of a character, and is followed by a stop signal which serves to bring the receiving mechanism to rest in preparation for the reception of the next character.

System, Synchronous: A system in which the sending and receiving instruments are operated continuously at substantially the same frequency, and are maintained, by means of correction if necessary, in a desired phase relationship.

Synchronous Transmission: A transmission process in which the significant instants in the overall stream are controlled by signals which occur at regular intervals, so that between any two significant instants in the overall stream there is always an integral number of unit intervals.

Tape, Relay, Torn Tape (Manual): A manual method of store-and-forward teletypewriter operation, wherein incoming messages are received on printed/perforated tape and are separated by tearing the tape so that individual messages may be processed and hand-carried to the appropriate outgoing channel(s) in accordance with routing requirements.

Tape Transmitter: In telegraphy, a tape transmitter is a machine for keying telegraph code signals previously recorded on tape.

Telecommunications: Any transmission, emission, or reception of signs, signals, writings, images, sounds, or intelligence of any nature by wire, radio, visual, or other electromagnetic means.

Telegraph Selector: A telegraph selector is a device which performs a switching operation in response to a definite signal or group of successive signals received over a controlling circuit.

Telegraph Sender: A telegraph sender is a transmitting device for forming telegraph signals. Examples are a manually-operated Morse key and a printer keyboard.

Telegraph Signal Distortion: Telegraph signal distortion is time displacement of transitions between conditions, e.g., marking and spacing, with respect to their proper

relative positions in perfectly timed signals. The total distortion is the algebraic sum of the bias and the characteristic and fortuitous distortions.

Telegraph Transmission Speed: Telegraph transmission speed is the rate at which signals are transmitted, and may be measured by the equivalent number of dot-cycles per second or by the average number of letters or words transmitted and received per minute. **NOTE:** A given speed in dot-cycles per second (often abbreviated to dots per second) may be converted to baud by multiplying by 2. The baud is the unit of signaling transmission speed recommended by the CCITT. Where words per minute are used as a measure of transmission speed, five letters and a space per word are assumed.

Telegraph Transmitter: A telegraph transmitter is a device for controlling a source of electric power so as to form telegraph signals.

Terminal, Carrier: A carrier terminal is the assemblage of apparatus at one end of a carrier transmission system, whereby the processes of modulation, demodulation, filtering, amplification, and associated functions are effected.

Test, Communications: Any transmission or reception of information directed specifically to evaluate the degree of responsiveness of communications media and/or facility(ies). **NOTE:** An example is the standardized text "SQ9" recommended by CCITT (R-51) for measurements of the degree of service distortion.

Tone-Modulated Waves: Tone-modulated waves are waves obtained from continuous waves by amplitude modulating them at audio frequency in a substantially periodic manner.

Transition, Signal: The change from one signaling condition to another; e.g., the change from mark-to-space or from space-to-mark. See significant interval.

Transmission, Double-Current: See polar direct current telegraph system.

Transmission, Parallel (Coincident Transmission): The simultaneous transmission of a certain number of signal elements, e.g., the use of a code according to which each signal is characterized by a combination of 3 out of 12 frequencies simultaneously transmitted over the channel.

Transmission, Serial (Sequential Transmission): Transmission at successive intervals of signal elements constituting a data or telegraph signal. **NOTE:** The sequential elements may be transmitted with or without interruption, provided that they are not transmitted simultaneously.

Trunk: (a) A single circuit between two points, both of which are switching centers and/or individual distribution points (Engineering). (b) A single or multichannel communications medium between two successive terminals (Administrative).

Trunk Group: (a) Two or more trunks between the same two points (Engineering). (b) A combination of trunks between specified terminals or geographical areas. In a broadband system, a trunk group will consist of two or more radio supergroups, separate groups, or a combination thereof (Administrative).

Two-Tone Telegraph: See keying, two-tone.

Two-Wire Circuit: A two-wire circuit is a metallic circuit formed by two conductors insulated from each other. **NOTE:** The term is also used in contrast with four-wire circuit to indicate a circuit using one line or channel for transmission of electric waves in both directions.

Unit Interval: In a system using an equal-length code or in a system during isochronous modulation (or demodulation), it is the interval of time where the theoretical durations of the significant intervals of a telegraph modulation are all whole multiples of this interval.

User: Any individual or organization, governmental or nongovernmental, military or civilian, authorized to use service provided by the Defense Communications System.

Voice Frequency Carrier Telegraphy: See multichannel telegraph, voice frequency.

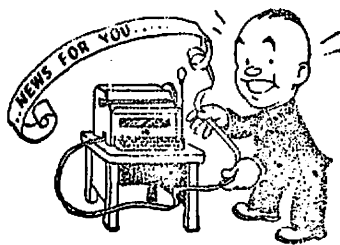
Word (Telegraph): By definition, a telegraph word shall consist of six character intervals when computing traffic capacity in words per minute.

$$\text{wpm} = \frac{\text{Mod rate} \times 10}{\text{Units per character interval}}$$

Appendix III

Abbreviations

AC	— Alternating Current	HF	— High Frequency (3-30 megacycles)
ACP	— Allied Communications Publication	I/O	— Input/Output
ADMS	— Automatic Digital Message Switch	IDF	— Intermediate Distributing Frame
AFC	— Automatic Frequency Control	ILU	— Incoming Line Unit
AM	— Amplitude Modulation	ISB	— Independent Sideband
ARQ	— Automatic Repeat Request	LTRS	— Letters key of teletypewriter
ASCII	— American Standard Code for Information Interchange	MA	— Milliamperes
ASR	— Automatic Send-Receive Set	MAU	— Multiple Address Unit
AUTODIN	— Automatic Digital Network	MDF	— Main Distributing Frame
CCITT	— Comite Consultatif International Telegraphique et Telephonique	MRC	— Modulation Rate Converter
CONUS	— Continental United States	M-S	— Mark-to-Space
CRC	— Communications Relay Center	M-STD	— Mark-to-Space Transition Delay
CTCF	— Channel Technical Control Facility	OLU	— Outgoing Line Unit
DC	— Direct Current	R/O	— Receive-Only Page Printer
DCA	— Defense Communications Agency	RT Set	— Reperforator-Transmitter Set
DCS	— Defense Communications System	S-M	— Space-to-Mark
DOD	— Department of Defense	S-MTD	— Space-to-Mark Transition Delay
FDM	— Frequency Division Multiplex	S/N	— Signal-to-Noise Ratio
FEC	— Forward Error Correction	S/R	— Send-Receive Page Printer
FIGS	— Figures key of teletypewriter	TDM	— Time-Division Multiplex
FM	— Frequency Modulation	TDMS	— Telegraph Distortion Measuring Set
FPIS	— Forward Propagation Ionospheric Scatter	TELEX	— Teleprinter Exchange
FPTS	— Forward Propagation Tropospheric Scatter	UHF	— Ultra-High Frequency (300-3,000 megacycles)
FSK	— Frequency Shift Keying	VF	— Voice Frequency
		WADS	— Wide Area Data System



Appendix IV

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